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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE STUDY OF IGNEOUS ROCKS[1]

No branch of petrology presents so attractive a field for investigation and study as that concerned with the origin and formation of igneous rocks. The great problems of metamorphism that traverse so much of the earth's dynamic history and involve so many factors common to the problems of igneous rocks are less alluring because of their greater complexity, and less definite character. While much is being done in each of these fields of rock study, it is to the former that I wish to call attention at this time. It is interesting to note how the attitude of the petrographer toward the subject of igneous rocks has changed with increasing knowledge of their composition, and with advancing experience with the fundamental laws of physics and chemistry.

Rocks that were considered igneous a century ago were almost wholly those known to have poured forth from volcanic craters, and were, for the most part, compact, aphanitic lavas, often containing porphyritic crystals—distinctly volcanic rocks. The great number of phanerocrystalline massive rocks were not generally considered as having the same character and origin as volcanic rocks, as being igneous. Their formation was explained in different ways by various geologists. And when treated

[1] Address of the vice-president and chairman of Section E—Geology and Geography—American Association for the Advancement of Science, Baltimore, 1908.

as "plutonic," were still thought of as different from "volcanic" rocks. Some of the commonest were considered as extreme forms of metamorphism, and have been so treated until quite recent times by eminent geologists.

Not only the geological mode of occurrence of many of these rocks was unknown, or only partially known, but the inherent, material characters were often matters of conjecture. Before the introduction of the microscope by Sorby, in 1850, the mineralogical study was confined to the larger, megascopic crystals, except for the microscopical investigation of rock fragments and powder by Cordier in the first decade of the last century. And the early chemical analysis of rocks, while adding considerably to a knowledge of their composition as a whole, lacked the completeness and accuracy of modern analytical methods, and failed to explain the composition of the rocks because of the absence of satisfactory knowledge of the mineral components.

With improved methods of investigation, geological, mineralogical and chemical, knowledge of the character and composition of rocks advanced. The supposed distinction between "volcanic" and "plutonic" broke down, or assumed new definition, through the observations and writings of Judd and others. The term "igneous rocks" came into more general use, and embraced all "volcanic" and "plutonic" masses. The mineral composition of all crystallized igneous rocks became known in more and more exact terms, though much remains at present to be learned of the definite chemical composition of some of the common mineral components of most rocks. Chemical analyses of rocks are becoming more complete, and more frequent in petrographical publications, and the store of chemical data is steadily increasing and has been made more available by the collections of rock analyses published by Roth and more recently by Washington.

The description of igneous rocks has been largely fortuitous. As rocks happen to have been encountered in geological field work, they were collected, and not always with due regard to their geological relations to other rock bodies; and subsequently they were investigated in the laboratory, more or less thoroughly, and described, often very imperfectly. Up to recent times the terms "petrography" and "petrographer" applied satisfactorily to the subject and to the worker in it, for the work was chiefly descriptive.

Generalizations regarding the nature of igneous rocks, or the formulation of laws controlling their crystallization, were largely empirical dicta not infrequently based on incomplete knowledge or inadequate experience. As a natural consequence of the haphazard manner of growth of the science, there has been an unsystematic nomenclature, derived from many sources at widely remote times, expressing markedly different degrees of information regarding the thing described—rock, texture or relationship—and in many instances representing in a single term a series of definitions varying with shifting opinion or advancing knowledge. Such, for example, as syenite, granite and trachyte.

At the present time attempts are being made to apply to the study of igneous rocks the results of laboratory experience in physical chemistry and, not only to investigate directly the physical behavior of molten rock minerals singly and in combinations, or mixtures, but to apply the more advanced laws of physicochemical reactions to the elucidation of the problems of crystallization, differentiation and mineral composition. The researches of Day and his colleagues in the geophysical laboratory of the Carnegie Institution of Washington, D. C., upon temperatures of

fusion, crystallization, and transformation points of silicate compounds corresponding to rock minerals, and of the behavior of mixtures of pairs of such compounds in producing mixed crystals, new compounds or eutectic mixtures, are of the first importance. The accuracy of the methods employed and the thoroughness of the work guarantee the value of the results and their permanency. In addition to the establishment of improved, or entirely new, methods of operation of a purely physical character tributary to the study of petrological problems, they have determined the isomorphism and physical behavior of the lime-soda-feldspar series; the relations of the various lime-silica compounds to one another; those of the lime-magnesia-metasilicate series; the melting and transition points of quartz and tridymite, and the character of still other compounds, and they have materially extended our knowledge of solid solutions.

Doelter and his pupils have studied the fusibility of the rock minerals and their solubility in one another, but the methods employed are less accurate than those just mentioned and involve a large element of subjectivity. They are approximations to the facts desired, often of much value qualitatively, but sometimes misleading. Other recent and valuable qualitative work in this field has been done by Morozewicz, while earlier work is represented by the classic researches of Daubrée, Fouqué, Michel-Lévy and others.

The most obvious result of the earlier efforts was the demonstration of the adequacy of fusion and gradual cooling, at ordinary atmospheric pressures, to bring about the crystallization of many minerals found in igneous rocks; and the necessity of some catalytic agency to promote the crystallization of other minerals common to these rocks. Such actions were ascribed to "mineralizing agents," or "crystallizers," assumed to be in most instances dissolved gases, chiefly H_2O. One of the most significant facts brought to light by the researches of Day and his colleagues is the new conception of high viscosity found in alkali-feldspars and quartz. Viscosities so great at temperatures near the transition point of liquid to crystal phase as to be indistinguishable within the two phases. That is, the viscosities of the amorphous glass and of the crystallized mineral are so nearly identical that the two phases of the substance react alike toward mechanical stress. Molecular mobility is so slight that readjustment from crystalline arrangement to the homogeneous chaos of liquid molecules is accomplished with such extreme slowness that the time of ordinary laboratory observation is not sufficient for its detection. However, the time available for ordinary "geological" processes, so called, is sufficient, as shown by the devitrification of volcanic glasses composed of these constituents—ancient rhyolitic obsidians. The function of a catalytic agent, as a gas dissolved in such a viscous liquid, is obvious—the viscosity is reduced and molecular mobility increased. If the transition is toward the liquid phase, solubility of the crystal is increased. If it is toward the crystal phase, the rate at which crystallographic molecular arrangement is accomplished is increased. The dissolved gas becomes a "crystallizer," or "mineralizing agent." Other substances, such as mineral compounds, yielding less viscous liquids than those of the alkali-feldspars and quartz, when dissolved in the more viscous liquids, reduce their viscosity in the same manner, though not to the same extent, as dissolved gases. They must behave catalytically toward crystallization, as gases do. Their behavior in this respect has not been generally recognized, though the function of certain liquid compounds, as fluxes, or as "mineralizing agents," is well known.

Thus the improvement in methods of

physical research is steadily enlarging the field of petrological investigation, and the advancement in the knowledge of physico-chemical laws is furnishing the investigator with new tools for the work and more efficient means for attacking the problems of igneous rocks. Foremost in the ranks of those who have attempted the application of modern conceptions of physical chemistry to the elucidation of the phenomena of texture and mineral composition and of the genetic relationships of igneous rocks is Vogt, whose earlier studies of furnace slags opened the way for the explanation of many analogous phenomena in the more refractory, volcanic lavas. Chief among these are the apparent order of crystallization of different minerals in slags, as indicated by their shapes and relations to one another as inclusions, and the relation between these orders and the composition of the mixture from which they crystallized. Vogt's observations were found to be in accord with modern theories of solutions, as Bunsen foretold in 1861, when he affirmed his belief that rock magmas are solutions of silicate compounds liquid at high temperatures. Vogt has called the attention of petrologists to these modern theories as developed by Arrhenius, van't Hoff, Ostwald, Gibbs, Meyerhoffer, Roozeboom and others. He has also made definite application of them to some of the phenomena and relationships mentioned. His publications have extended widely the horizon of modern petrology, which by the assumption of these broader, deeper phases of the study of igneous rocks, and of similar problems affecting metamorphic rocks, has passed beyond the narrower boundary of petrography, strictly so called.

The evolution of chemistry from a state of pure empiricism to one of comparatively logical sequence has placed before us a collection of coordinated laws, which, while incomplete, or subject to numerous exceptions, furnishes us with means to postulate reactions between the constituent elements of rock magmas with reasonable assurance of correctness, or to explain the formation of mineral compounds hitherto in a measure enigmatical. Much remains to be more firmly established, both as to the chemical character of the elements and their compounds, and with regard to theories relating to their reactions, and even to the very nature of their existence in some instances. The silicate compounds constituting igneous rocks remain largely uninvestigated, so far as concerns their synthesis and reactions in mutual solution. And the physical study of solutions and of their transitions to the solidified components—especially the more complex mixtures—is far from completed. The present is a period of transition in the development of petrology, as were also times past. But the changes taking place at this time appear to be so many and so fundamental that it may well be asked whether the older methods of approach to the study of igneous rocks should not be replaced by others more in accord with present conditions of knowledge of chemistry, physics and of the rocks themselves. The older method, in the nature of things, was, and is largely at the present day, objective, and the expressions of relationships or laws empirical.

It would seem more reasonable to begin a systematic study of igneous rocks with a consideration: of the most fundamental characteristics of the magmas from which they have solidified; of their constituents, together with their probable chemical reactions and the resulting mineral compounds; of the manner in which these may separate from a silicate solution, or rock magma; of the shapes they are likely to assume upon crystallization and the consequent texture of the rock. Processes of molecular separation of magmas lead to the discussion of the differentiation of magma into chem-

ically unlike parts and the resulting different varieties of igneous rocks, together with their eruption and solidification as geological bodies of various kinds.

Assuming a certain elementary acquaintance with rocks on the part of the student, which is acquired in courses in general geology, the systematic treatment of the subject should begin by calling attention to the chemical composition of unaltered igneous rock as shown by analyses, published in many descriptions of rocks, but most conveniently found in comprehensive collections in Bulletins of the U. S. Geological Survey and in the tables of analyses edited by Justus Roth and more recently by H. S. Washington. The extremely variable nature of these data and their great abundance present such an exceedingly complex set of numerical relations that their statement, or discussion, requires the aid of diagrams by which the problem may be greatly simplified.

In addition to the chemical elements noted in ordinary rock analyses there is a much greater number known to occur in rare minerals that crystallize from rock magmas in special instances, or that oftener appear in certain varieties of igneous rocks, such as the pegmatites. A consideration of all known pyrogenetic minerals with respect to their chemical composition calls attention to the compounds that are repeatedly formed in igneous magmas by the union of the elements that existed in the magmas before their solidification. And by arranging them in accordance with the order of their constituent elements in the Mendeléeff series valuable information as to certain chemical relationships among these compounds is at once furnished.

The substances occurring in igneous rocks are in most cases solids, less often liquids or gases. The solid compounds are always in crystallized condition. Amorphous, glassy solids that sometimes occur in igneous rocks are seldom, if ever, definite chemical compounds, but are mixtures. The crystallized substances (minerals) are rarely present as uncombined elements, such as gold, graphite and metallic iron. A few are simple compounds with invariable composition, as SiO_2 (quartz), TiO_2 (rutile), Al_2O_3 (corundum). Most of them are complex and variable in composition, owing to the presence of isomorphous mixtures, as the feldspars, olivine, amphiboles. There are very few examples of polymorphism, such as quartz and tridymite. The apparent difference in the crystallization of orthoclase and microcline is probably due to submicroscopic multiple twinning in the apparently more symmetrical form. Polymorphism of some of the pyrogenetic compounds, as $MgSiO_3$ and $CaSiO_3$, which is known in laboratory products is not clearly developed in pyrogenetic minerals.

Certain isomorphous mineral compounds are not developed in igneous magmas with like frequency, or in certain cases not at all. Such, for example, are the hexagonal compounds $NaAlSiO_4$ (sodium-nephelite), $KAlSiO_4$ (kaliophilite), $LiAlSiO_4$ (eucryptite). Compare also the potash-, lithia- and soda-micas. Other compounds that are analogous chemically and might be expected to crystallize isomorphously in igneous magmas have quite different crystal symmetry, as is the case with $KAl(SiO_3)_2$ (leucite), $NaAl(SiO_3)_2$ (jadeite), $LiAl(SiO_3)_2$ (spodumene).

Various silicate compounds involving different silicic acids: orthosilicic, metasilicic, polysilicic and in rare instances disilicic, besides uncombined silica, may crystallize from the same rock magma. And even base-forming elements, as iron and aluminium, may, under some conditions, separate from rock magmas as oxides without combining with silica, which may itself separate as SiO_2. That is, hematite, magnetite or corundum may crystallize in the pres-

ence of quartz. On the other hand, certain lower silicates do not form when there is sufficient silica to form higher silicates with the same bases. Thus $KAl(SiO_3)_2$ (leucite) and $NaAlSiO_4$ (nephelite) do not occur pyrogenetically with SiO_2 (quartz).

Moreover, it is well known that some rock magmas, especially those of intermediate composition, crystallize under one set of conditions into certain combinations of minerals, and under others into other combinations, certain minerals appearing in one case and not in another, though the magmas from which they formed were chemically alike.

In order to account for the production of the mineral compounds known to occur in igneous rocks, as well as for the absence of others; and to understand the possibility of variation in the production of mineral compounds from any magma under variable conditions; and to comprehend the act of separation and crystallization of such minerals upon the solidification of the magma; it is necessary to consider the probable physical and chemical character of liquid rock magmas, especially the known physicochemical laws regarding solutions.

Discussions of the behavior of solutions under varying conditions of temperature and pressure involve theories of the possible molecular constitution of matter, gaseous, liquid and solid, which must be kept in mind in order to form any clear conception of the processes under consideration. The kinetic theory regarding the behavior of molecules of gas, liquid or solid, under variable temperatures and pressures, furnishes definite pictures of changes of state at transition points from one phase to another. Those with which the problems before us are most concerned are the critical point of gases, the melting point of solids, the solution or the separation points of solids in liquids and also the transition point between two crystal phases of the same compound (such as that between quartz and tridymite).

Since liquid rock magmas are solutions of silicate compounds in one another, all that is known of the physical and chemical behavior of solutions is germane to the discussion. This includes the solution of gases, liquids and solids, in liquids; and eventually their solution in solids; the solubility of various substances in liquids of other substances; the possible molecular constitution of liquid solutions; the existence of molecules of different degrees of complexity, and the dissociation or ionization of some compound molecules; the laws relating to diffusion, and the relative diffusibility of various compounds; those relating to the molecular concentration—the saturation and supersaturation of solutions. The chief qualifying factors in this discussion are the chemical composition of the several compounds; the possibility of changes in chemical equilibria; the viscosity of the solution; the temperature, pressure and the time through which any operation acts. The possibility of producing in a colloidal condition one of the compounds, $Al(OH)_3$, $Fe(OH)_3$ or $Si(OH)_4$, by the interaction of the hydroxyl (OH) and aluminium (Al), iron (Fe), or silicon (Si), is also to be taken into consideration.

In a solution containing the chemical elements common to igneous rocks reactions should take place between them in accordance with known chemical laws, and with results corresponding to observed pyrogenetic mineral compounds. Some of the fundamental laws relating to chemical reactions among the elements are based upon conceptions of chemical energy and activity, and of the conditions that modify their effects. An important factor in chemical processes is, often, a catalytic agent that promotes reactions without itself appearing as a component of the final products. The

chemical behavior of ionic substances, and especially the hydrolyzing action of ionized water, are other factors in the problem under consideration. The relative strength of chemical activity in the base-forming, or acid-forming, elements, and their ability to form acids and salts, lead to the discussion of the production of the pyrogenetic minerals from liquid magmas composed of elements found in igneous rocks; some of these minerals having been produced in the laboratory by melting together the component elements in proper proportions.

Considering what should take place in a solution having the composition of an average of all igneous rocks, it can be shown, since the chief acid-forming elements present are silicon in large amount, and the more active element phosphorus in very small amount, that salts with these elements in the acid radical must be common. Other acid-forming elements occurring in small amounts are titanium and zirconium; while iron and aluminium may play this rôle under favorable conditions. The more active, phosphoric, acid forms unstable salts with the active base-forming metals, potassium and sodium, but a very stable compound with the less active metal, calcium, into which compound fluorine, or chlorine, enters; yielding apatite, an almost universal component of igneous rocks.

Silicon is known in the laboratory to form one definite acid, H_4SiO_4, orthosilicic acid; and other acids of silicon have not been isolated and identified. But very definite mineral compounds exist that indicate that salts from other silicic acids form under proper conditions. These are:

H_4SiO_4, orthosilicic acid;
H_2SiO_3, metasilicic acid;
$H_4Si_3O_8$, polysilicic acid;
$H_2Si_2O_5$, disilicic acid.

It is significant that in laboratory experience with orthosilicic acid, H_4SiO_4, prepared from aqueous solutions, the compound may be made to lose water gradually until nothing but silica, SiO_2, remains. In this way free silica may be separated from a silicate compound, a hydrogen silicate; since an acid may be considered as a hydrogen salt.

Observations upon the pyrogenetic minerals, and laboratory experience with synthetical operations, show that salts of several kinds of silicic acids form by the side of one another, and that their character and amount depend on the nature of the base-forming elements present in the mixed solution. Orthosilicates, metasilicates and polysilicates commonly form in the presence of one another, sometimes accompanied by uncombined silica. And it becomes more and more evident that the formation of the different kinds of silicic acid ions, or their salts, is controlled primarily by the strength, or chemical activity, of the base-forming elements; is dependent also on the amount of silica available in the solution; and may be modified, of course, by other factors. Thus it appears that the most active metals command the highest silicic ions, the highest silicates common in igneous rocks being the polysilicates of the alkalies, potassium and sodium—orthoclase and albite.

Further, the abundance of aluminium in most rock magmas results in the presence of abundant aluminous compounds. And this element, which is relatively inactive chemically, being found sometimes in the basic, sometimes in the acid radical, is oftenest combined with the strongest base-forming elements, potassium and sodium. These relations are illustrated by the following common, simple pyrogenetic minerals.

It is well known that the orthosilicate of sodium and aluminium (nephelite) and the metasilicate of potassium and aluminium (leucite) do not form in the presence of free silica (quartz), while metasilicates

Polysilicates	Metasilicates	Orthosilicates
$K-Al\equiv$ (orthoclase)	$K-Al\equiv(SiO_3)_2$ (leucite)	$Na-Al\equiv(SiO_4)$ (nephelite)
$(_2O\ {}^{N}_{Al\equiv}(Si_3O_8)$ (albite)		$Al\equiv(SiO_4)$ $Ca=Al\equiv(SiO_4)$ (anorthite)
	$Ca=(MgFe)=(SiO_3)_2$ (diopside)	$Si(_2,\ )$
	$(Mg, Fe)_2=(SiO_3)_2$ (hypersthene)	$(Mg, Fe)_2=(SiO_4)$ (olivine)

and orthosilicates of the less active metals, calcium, magnesium and iron (pyroxenes, olivine and anorthite) do. The relative chemical activity of all of the elements common to igneous rocks may be illustrated in like manner, and the probabilities of various pyrogenetic mineral compounds forming from different rock magmas may be made clear.

One of the most important factors in the discussion of the chemistry of igneous rocks is the rôle of hydrogen, whether as an active base-forming element, or as a catalytic agent, alone, as hydrogen (H), or combined with oxygen, as hydroxyl (OH). Its exact behavior in each specific case is not definitely known, but the principles applicable to several distinguishable cases are clearly established.

Adopting the idea that an acid is a hydrogen salt in which hydrogen plays the rôle of a positive, base-forming element, an acid salt may be considered as one in which all of the hydrogen has not been replaced by other base-forming metals. Such an acid salt may be looked upon as a substitution derivative from a hydrogen salt (acid), or from a normal salt by the introduction of hydrogen in place of other positive metals. An example of such a compound among pyrogenetic minerals is to be found in muscovite $(K, H)Al(SiO_4)$. This might be derived from H_4SiO_4, $KAl(SiO_4)$ or $Al_4(SiO_4)_3$. The formation of such a compound involves the presence of active hydrogen to play the rôle of metal. Muscovite is a common pyrogenetic mineral in some igneous rocks rich in silicon, with much uncombined silica, and also in others comparatively low in silica, accompanying orthosilicate and nephelite. It forms by the side of polysilicates—orthoclase and albite—and even with the disilicate, petalite. The formation of muscovite must be ascribed to the action of hydrogen upon silicon, either directly in the first instance, or, if previously formed silicates of aluminium and potassium be assumed to be the source of the compound in question, then its action in replacing part of the potassium must be that known as hydrolysis, whereby the hydrogen ions from water replace metals in the salt through a process of double decomposition.

It is known that the chemical activity of hydrogen even toward a gas, like oxygen, is greatly increased by rise of temperature; hydrogen being rather inert at ordinary temperatures. The relative activity of hydrogen and potassium toward silicon is indicated by the fact that the highest hydrogen silicate definitely known is the orthosilicate, H_4SiO_4 (orthosilicic acid), whereas potassium commonly occurs in a polysilicate, $KAlSi_3O_8$ (orthoclase). It has been found impossible to produce mica in open cru-

cibles from which hydrogen, or water vapor, naturally escapes at high temperatures. And muscovite is not formed pyrogenetically in surface lavas, or, if so, to a very small extent as compared with its occurrence in rocks crystallized under considerable pressure. From these facts it must be concluded that the formation of the acid orthosilicate (muscovite) in the presence of polysilicates and free silica must be assigned to the chemical activity of hydrogen at high temperatures under sufficient pressure to hold it in the liquid magma solution.

The same argument as to the action of hydrogen in rock magmas applies to the production of the other micas, biotites and lepidolite. These compounds are complex mixed salts, and the composition of biotite involves the production of orthosilicates of magnesium and iron, which are present in biotite. These orthosilicates develop in magmas together with metasilicates of magnesium and iron—pyroxenes and hornblende—and with uncombined silica, quartz. The same compounds when alone form olivine, which generally does not develop in magmas with uncombined silica, quartz, but probably occurs with quartz oftener than has been supposed. In both of these cases the production of orthosilicate of magnesium and iron in the presence of "free" silica in magmas in which the metasilicate might be expected to form is probably due to the hydrolyzing action of water at high temperature. That is, the hydrogen at high temperature combined with some of the silicon, that otherwise would have united with magnesium and iron as metasilicate, and formed orthosilicate of these metals and orthosilicate of hydrogen.

$$(Mg, Fe)_2(SiO_3)_2 + 2H_2O \rightleftarrows (Mg, Fe)_2(SiO_4) + H_4(SiO_4).$$

Should conditions of saturation favor the separation of the magnesium-iron compound in the solid phase, olivine would crystallize; and with falling temperature the hydrogen silicate would split up into water (H_2O) and silica (SiO_2), with the eventual crystallization of quartz.

When the amount of silica is great as compared with that of magnesium-iron orthosilicate it is possible for quartz to separate before the orthosilicate, as is the case in many hollow spherulites and lithophysæ, where fayalite, $(Fe(Mg))_2SiO_4$, is apparently almost the last mineral to crystallize, and rests upon the surface of abundant quartzes. The dependence of these forms of crystallization upon the presence of water in the magmas has been clearly demonstrated.

Other mineral compounds, whose production in igneous rocks must be referred to the hydrolyzing action of water, are amphiboles, which, as Penfield has shown, contain as an essential constituent notable amounts of hydrogen. The development of hornblende in igneous rocks appears to be dependent on conditions similar to those controlling the development of biotite, for they commonly accompany one another in rocks of intermediate composition when either is present. The particular kind of amphibole which forms in rock magmas depends primarily on the proportions of elements present, and secondarily on attendant conditions which produce variation in amphibole from one magma, which is strikingly illustrated in the two igneous rocks from Gran, Norway, described by Brögger.[2] The magmas have almost the same chemical composition, yet one crystallized into a mixture of hornblende and lime-soda-feldspar, while the other crystallized almost completely into hornblende, which contains all the components of the

[2] Brögger, W. C., "Erupt. Gest. kp. Geb.," Vol. III., 1899, p. 93, and *Quart. Jour. Geol. Soc.*, Vol. L., 1894, p. 19.

feldspar and hornblende in the first-mentioned rock.

That hornblendes are less stable compounds in igneous magmas than pyroxenes and numerous other minerals, is shown by the frequent occurrence of paramorphs of other minerals after hornblende, commonly seen in so-called black borders, and the absence of correspondingly changed crystals of other minerals.

Another chemical principle involved in the production of pyrogenetic minerals is that affecting the formation of compounds that possess common ions when in solution. It is known that when there are in a solution ions capable of entering two or more compounds, the concentration of the least soluble compound may be increased by the entrance of ions derived from other compounds into its molecules. And this may proceed to the complete incorporation of the common ions within one compound upon its separation in the solid phase. This has sometimes been called erroneously "mass action." That compound forms at the expense of another in any particular instance which is the more stable under attendant conditions. Illustrations of this action are found: in the case of the complex amphibole in the hornblendite of Gran already mentioned; in aluminous pyroxenes (augites), which contain components capable of forming lime-soda-feldspars, as pointed out by Pirsson, and in numerous other rock minerals. This principle is probably concerned in the production of the lime-soda-feldspars with notable amounts of albite molecules, as in andesine and labradorite, in magmas so low in silica as to necessitate the production of leucite from the potassium present, when the more active potassium should have combined with the silicon in a polysilicate (orthoclase), leaving the less active sodium to enter orthosilicate (nephelite).

Following out the discussion of all the probable compounds likely to form under known chemical laws from molten rock magmas upon cooling, and taking into consideration the relative chemical activities of the several constituent elements in igneous rocks, it is possible to deduce a probable mineral composition for any given magma, under given conditions of cooling. The mineral composition of igneous rocks then becomes a necessary consequence of the chemical reactions likely to obtain in molten rock magmas, and depends not only on the kinds and amounts of the elements present in each case, but also on the conditions of temperature and pressure modifying the chemical activities of the elements and the stability of the compounds. As these conditions are known to vary with the experience of different magmas during eruption and solidification, the minerals produced in chemically similar magmas are not to be expected to be always alike, and the variations in composition are in this way understood.

Having considered the possible chemical reactions that may give rise to mineral compounds in rock magmas, the next step in the treatment of the subject is a discussion of the process and results of separation of various compounds or substances from magma solutions upon change of physical conditions attending the eruption of magmas. These may separate as gases, liquids or solids, chiefly as solids. But gases escape in large volumes upon the eruption of lavas, mostly as water vapor. There are other kinds in smaller, though often in considerable, amounts. The effects of this loss of gases are in the chemical composition of the rock magma, in the concentration of the remaining substances, and in the viscosity of the magma, which may increase notably upon loss of gas.

Liquids, probably, do not separate as such from molten magmas to any consider-

able extent. Apparently liquid silicates are miscible in one another in all proportions, though suggestions that they may not be have been advanced by some petrologists. It is known that liquid sulphides and silicates are not miscible in all proportions at all temperatures. And where sulphides exist in large amounts, separation in the liquid phase may take place with falling temperature.

Separation of solids from solution depends upon the attainment of a sufficient molecular concentration of substances to saturate the solution. Saturation may be brought about in several ways: by chemical reaction within the solution consequent upon a change of chemical equilibrium; by change of temperature, usually by lowering temperature; by change of pressure, either acting in an opposite manner from temperature or by affecting the gas content.

Solids may separate when the point of saturation for them has been reached, or the liquid may become superheated, and separation be delayed. In this condition separation is often induced by the insertion of a solid of like composition, or of an isomorphous compound, or by agitating. Such a condition of a liquid has been called *metastable,* and in this condition, as shown by Miers in laboratory observations on liquids of organic compounds, crystallization of the separating substance takes place, at relatively few points, and proceeds gradually, according to degree of concentration and other factors, until comparatively large individuals are formed. If supersaturation proceeds without separation of solid phase a point will be reached when separation will take place spontaneously at many points in the liquid and continue rapidly. This is the *labile* condition of the liquid. When this condition is reached by a cooling liquid crystallization often takes place suddenly as a shower of minute individuals, as observed by Miers. The bearing of these facts on the textures of igneous rocks is apparent, and a knowledge of the laws relating to the separation of solids from liquids; the order in which those of different substances may follow one another in a mixed solution; the separation of isomorphous compounds; and the shapes that may be assumed by the resulting crystals of various minerals lead to an understanding of the texture of igneous rocks.

A supersaturated condition is more readily obtained in more viscous liquids, which are more apt to solidify without crystallization, as glasses, than more fluid liquids. The most familiar illustrations of this law among igneous rocks are the persilicic (rhyolitic) lavas, which often form glasses (obsidians). The question has been raised by Crosby, and others, whether an earthquake happening when a magma was in a sufficiently supersaturated, metastable, condition might not induce crystallization of some of the constituent compounds.

Crystallization may begin with different degrees of supersaturation of the liquid, and would proceed at different rates according to the degree of supersaturation, being more rapid the greater the concentration. It would also be more rapid the greater the molecular diffusivity, that is, the lower the viscosity of the liquid, and the greater the rate of cooling, so long as this does not increase viscosity too rapidly. Gradual or slow crystallization at comparatively few centers would yield relatively few, large, crystals; whereas sudden, rapid crystallization from many centers would produce many small ones.

High fluidity in solutions would permit easy diffusion of separating molecules toward crystallizing centers, favoring the growth of relatively large individuals. High viscosity would retard diffusion and

favor the growth of many small crystals. This is well illustrated by the laboratory experience of Day with the crystallization of various lime-soda-feldspars. Thus it was found that 100 grams of liquid anorthite crystallized completely in ten minutes to fair-sized crystals, and it required quick chilling to prevent its crystallization and to produce glass. A mixture of equal parts of anorthite and albite (Ab_1An_1) required a gradual cooling extending over several days to effect complete crystallization, whereas liquid albite could not be induced to crystallize through days of cooling in an open crucible. Comparing the size of the crystals of anorthite produced in 10 minutes with those of oligoclase-andesine (Ab_3An_1) which were produced by gradual cooling through two days, the former were from 3 to 5 mm. thick, the latter about 0.005 mm. thick. That is, the more liquid anorthite produced crystals one thousand times as thick in about one three-hundredth the time, a ratio of 300,000 : 1.

The rate of separation of solid from liquid also depends on the solubility and the amount of any substance in solution. The greater each of these factors the more rapid the rate of crystallization and the larger the crystals, other things being constant in compared cases. This law has been expressed definitely by von Pickardt as follows: "The velocity of crystallization (separation in solid phase) is diminished by the addition of foreign substances to the liquid phase of a substance, the diminution of the velocity being the same for equimolecular quantities of all substances."

The order of succession in the separation of different kinds of minerals from molten magma is a subject upon which there has been some difference of opinion among petrologists. It has been clearly demonstrated that the order is not an invariable one. The laws relating to the order of separation of solids from mixed solutions have been definitely determined for solutions of various compounds in one another and the general principles are applicable to the study of igneous rocks. The attention of petrographers has been called to these laws by Vogt.

The order of separation of several compounds in solution in one another depends on the degree of saturation of each, that with the highest degree of saturation, or that one whose saturation point is reached first upon the cooling of the solution separates first. The relation between saturation, molecular concentration and the melting point of each compound has been established in general terms for different sets of cases by Meyerhoffer, and further elaborated by Roozeboom for cases of crystals of isomorphous compounds.

In all cases where the mixed compounds do not unite chemically to form new compounds, or physically as mixed crystals, there is one minimum point of temperature for a mixture of two compounds, and more than one in more complex mixtures, at which a certain proportioned mixture remains liquid. At this temperature the two components of a binary mixture will crystallize simultaneously. This minimum temperature and particular mixture are called eutectic.

Miers has shown that when supersaturation sets in and the labile condition is taken into account, the minimum temperature of separation and corresponding proportions of the mixture do not coincide with those already described as eutectic. These he has called hypertectic.

A study of these principles shows that there can be no invariable order of separation, or crystallization, of the constituent compounds in a series of mixed solutions composed of like compounds. And that simultaneous crystallization of pairs, or of

more than two kinds of separating compounds, may take place in solutions of whatever composition. Eutectic mixtures may consist of more than two components. Moreover, the supersaturation of a solution by one component may affect the proportion between two or more components at the moment of synchronous crystallization. Synchronously crystallized mixtures of certain kinds of components, therefore, are not necessarily similarly proportioned. The bearing of these principles on the crystallization and texture of igneous rocks is manifold. A few illustrations will suffice. Quartz may be the first mineral to separate from a molten magma when the solution is so rich in silica that upon cooling it becomes saturated with silica before being saturated with feldspar or some ferromagnesian compound, or even iron oxide. Quartz may be the last mineral to separate from magmas so rich in feldspar or ferromagnesian compounds as to become saturated by these upon cooling before being saturated with quartz.

Either labradorite or augite may separate first from a mixture of the two, according to which saturates the solution first upon cooling, and this depends on their relative amounts in the solution, and their order of crystallization is further modified by the possibility of one or the other producing supersaturation in the liquid. This will account for the differences of texture often noted in certain gabbros, or basalts, of almost the same composition.

Eutectic mixtures, or those whose components crystallize simultaneously, often yield aggregates of intergrown crystals, the most familiar examples of which are found in graphic granite, and certain alloys. But Miers has called attention to the fact that the simultaneous crystallization of two compounds in eutectic proportions does not invariably produce intergrown individual crystals, or graphic intergrowths. It may result in granular aggregations of concerted, adjacent anhedrons not intergrown, which corresponds to observations on the textures of igneous rocks, for many rocks of like composition in some instances exhibit graphic texture, in others evenly granular texture. Accepting graphic intergrowth as evidence of synchronous crystallization, and of the existence of eutectic proportions in some cases between the several mineral compounds at the moment of crystallization, it is to be noted that such intergrowths have been developed in igneous rocks between quartz and potash-feldspar, quartz and sodic feldspars, quartz and biotite, feldspar and pyroxene, feldspar and hornblende, feldspar and nephelite, pyroxene and iron oxide (probably magnetite) and between other pairs of minerals.

The separation of solids, that is, the crystallization of minerals from rock magmas, must be an extremely intricate process, because of the complex character of the solution, the variable and irregular changes in temperature and pressure consequent on the movements of eruption, the variations in composition due to changes in gaseous components, and the possibility of chemical reaction among the components with changes of chemical equilibria, as well as the probable supersaturation of the magma by different components to various degrees. This complexity will doubtless prevent exact statements of the relations between composition and texture, but approximations may be made to the proper explanation of some of the most common and characteristic textures, which will render them more intelligible to the student.

The crystallization of a substance from solution involves molecular diffusion, and molecular orientation, and these are functions of molecular attraction, composition of the molecular compound, viscosity of the

liquid, composition of the liquid, temperature, pressure and time, or rate of changing conditions. The combination of these factors in the case of any cooling rock magma results in rock possessing a certain degree of crystallinity, which may range from a state of complete crystallinity, to the reverse, or complete glassiness. When more or less crystalline, the size of the crystals becomes a feature of consequence. The granularity, or the size of crystals in rocks, has been given a prominent rôle in most descriptions, and classifications of rocks. The shapes of individual crystals clearly give distinctive character to the pattern, or fabric, of rocks, and shape is largely a function of crystal structure and physical habit of specific minerals. The recognition of these relationships and their systematic treatment in the description and discussion of igneous rocks will lift the subject out of a maze of confusing, complex detail, usually treated in an uncoordinated and meaningless manner.

Application of principles of molecular diffusion; of laws relating to solution pressure, or osmotic pressure; of conditions controlling crystallization, or the separation of solids from solutions; of conditions affecting the physical character of liquids, or rock magmas; to the observed variability in the composition of igneous rocks, and to the known relation between their composition, order of eruption, and mode of occurrence, leads to conceptions of their origin from other magmas, by processes called by the general designation of *differentiation.*

With such an understanding of the causes of heterogeneity in rock solutions the great variability in the composition of igneous rocks as shown by chemical analyses, and by a quantitative study of their mineral composition, appears as the natural, as well as the logical, result of their mode of formation.

Mineralogical and constitutional facies of igneous rocks are readily comprehended; and the absence of fixed types of magmas, or of frequently recurring bodies of igneous rocks with definite or invariable composition, becomes "natural," and is the thing to be expected. Variations in texture within one rock mass, and among rock bodies having various modes of occurrence, are readily understood as the results of variability in the conditions attending volcanic eruption.

As to the possible character of volcanic eruption, some conception of it may be derived from a consideration of the probable condition of highly heated rock material under great pressure deep beneath the surface of the earth, as well as its probable experience in moving upward and out upon the earth's surface.

The high temperature of volcanic lavas when they reach the atmosphere, the fact that they were losing heat continually from the time of their first movement upward, the evidence that they were completely liquid at some stage in their eruption, together with the observed gradient of increase of temperature downward from the surface of the earth, all combine to show that rock magmas come from some region where the temperature is considerably above the melting point of igneous rocks. The behavior of the earth as a rigid globe, and the known effect of pressure in counteracting that of heat, together with its estimated high gradient of increase downward within the earth, force the conclusion that at sufficient depth magma, though hot enough to be liquid, behaves as a solid. Such conditions of heat and pressure can not vary abruptly from place to place, but must be nearly the same for large volumes of material; and differences of temperature and pressure must obtain very gradually, chiefly in vertical directions. Magma in

such a position must be in a virtually static condition until it experiences change of pressure or stress. Whatever its composition, it must remain unchanged.

A change of stress may come about by movement in the overlying portion of the earth. Orogenic movement, readjustment of the upper rigid, rock mass, from whatever causes, when profound, must affect the stresses in still deeper parts. The known crustal movements behave as bendings of the upper rock mass, which in places at the earth's surface appear to result in tensile stresses; in places, in compressional stresses. Beneath each of these the effective stresses must be of the opposite kind; under the tensile, compressive stresses, and under the upper compressive ones, tensile stresses. Tensile stresses should occur at some distance below ocean beds, and more especially along the borders of oceans and continents. Compressive stresses should occur, in general, beneath continental masses.

Tensile stress, as at the bottom of a synclinal arch, operating in a rigid mass must communicate itself downward as far as the mass behaves rigidly. When the hot mass is potentially fluid, that is, is kept solid by pressure, change of stress must be followed by change of position of the mass. A tendency to pull apart or stretch in the potentially fluid mass must be followed by a yielding of the mass. At a point sufficiently cool for the mass to act as a solid a tendency to fracture and to open a fissure would be followed by a movement of the slightly more heated mass beneath to occupy the space between the fractured solid; these differences of temperature and of rigidity are to be understood in a mathematical sense as differential, there being a gradation of physical conditions between adjacent parts of the mass. There will be no open space, or fissure, in the ordinary sense. But it must be understood that at whatever depth the mass may be considered solid, there it may fracture, part and become the walls of a layer or body of intruded liquid, provided the liquid have nearly the same density as the solid mass.

The statement made by Van Hise and Hoskins that open cracks, or fissures, can not exist at greater depths than about 10,000 meters was made on the assumption that the filling is water; the difference in weight of the rock and the hydrostatic pressure of the corresponding column of water being compared with the crushing strength of the solid rock. When the liquid is heavier than water the same method of calculation allows fissures filled with such liquid to exist at greater depths; and if the weight of the column of liquid equals that of the wall rock, the two will remain in equilibrium at any depth. Consequently at any depth in the earth mass where a tendency to part may exist, hotter and potentially more fluid material beneath may move up and permit the parting of the slightly more rigid mass to take place. This would appear to be the initial step in the eruption of rock magma.

As the mass shifts its position upward the pressure upon it decreases, resulting in some expansion of the volume, some decrease in density, some increase in mobility. And the rising mass is hotter than the masses between which it is rising, unless movement is at the same rate as the diffusion of heat. In proportion as the tensile stress is strong the upward movement will be pronounced, and may result in a flow of very dense, hot, viscous magma toward the surface of the earth. The greater the vertical distance traversed and the more rapid the rate of movement, the greater the difference in temperature between the magma and the enclosing mass.

That the eruption of rock magma is con-

sequent upon the adjustment of accumulated stresses within the overlying rocks is indicated by the sequence of fractures and lava flows in the uppermost parts of the earth, and the opening of eras of great volcanic activity after profound orogenic movements have disturbed the comparatively quiet action of forces that have been gradually shifting the stresses within the outer portion of the earth. The magnitude of the adjusting action is evinced by the extent of territory simultaneously affected. As, for example, the initiation of volcanic action on a gigantic scale throughout western America at the end of Cretaceous time, after an enormous period of nearly uniform conditions of comparative quiet.

The eruptive impulse, or energy, causing the upward flow of magma, must originate in the expansion of the magma upon relief of pressure consequent upon the adjustment of stresses in the overlying mass, and from expansive energy of dissolved gases. That the eruptive force is of nearly the same order of magnitude as the stresses within the earth's crust is shown by the relatively small amount of material erupted upon the surface of the earth compared with the bulk of the whole; by the common intrusion of magma along fracture planes and along those of structural weakness, rather than at random through rock masses; and most conspicuously, by the evidence of equilibrium with the atmosphere maintained by lava in volcanic craters. Open vents are known to exist for centuries without great extrusion of rock magma, as at Stromboli. The stresses which produce condensation of volume in proportion to depth and the results of expansion of volume are, therefore, somewhat evenly balanced.

The effect of expanding gases is shown in the explosive character of many eruptions, and the periodic character of all eruptions from open vents (volcanoes). It must increase the volume of all magmas as pressure is relieved. Its effectiveness must increase in proportion to the amount of gas in the magma, which may result from diffusion of gas from greater depths of magma, and also from accession from adjacent rocks under favorable conditions.

Spasmodic eruption may follow sudden yielding of overlying rocks to long continued stresses, as in the case of massive, or fissure, eruptions when there may have been no considerable explosive action of gas; or it may result from an accumulation of gas pressure sufficient to rupture overlying rock masses. Eruption is then accompanied by abundant evidence of explosion. Both causes undoubtedly operate together in most cases.

In so far as magmatic eruption is a result of volumetric expansion of the magma, due to relief of pressure, the shrinkage of volume due to cooling will retard eruption, or eventually stop it. Crystallization will operate in the same direction. In proportion as eruption is due to expansion of dissolved gas, the escape of gas from magma, or the reduction of supply, will lessen the force of eruption, or eventually put an end to it. The supply of gas from great depths may be reduced by the gradual diffusion of whatever is in a position to be appreciably diffused; or the supply from rocks adjacent to intruded magma may be cut off by the closing of pores in these rocks through metamorphism; porous rocks becoming dense and almost impervious to gases. In these ways eruptive action initiated by crustal readjustment after continuing for variable periods may come to an end. Readjustment of stresses may recur from time to time in any region, either at such widely remote periods that the volcanic activities associated with each readjustment constitute distinct and separate periods of action; or at such frequent intervals that the results of several profound movements are combined to form a

prolonged period of complex volcanic eruptions.

Independence of action at neighboring volcanoes, either as to period of eruption, volume of magma erupted, explosive or quiet character of action, or relative height of lava column in conduit of volcanoes, follows from local variation in the factors entering into the process of magma eruption, such as, the volume of magma involved in each conduit extending to profound depths, the shape of the conduit, the temperature of the magma; the rate of cooling; the amount of gas diffused in any given time; the character of the surrounding rocks; and the stability of the surrounding rock masses as a complex whole. The chemical composition of the magma is also a factor involved in the activity of a particular volcano. But the composition of the magma is also a feature by which volcanoes may show independence. Differences in the composition of rocks in neighboring volcanoes is to be sought in variation in the differentiation of magmas during the course of eruption from deep-seated to surficial positions.

Among the results of such differentiation may be mentioned the production of complementary rocks, which may occur in rock bodies of various forms. A special case of local differentiation, usually associated immediately with crystallization and solidification of parts of a magma, is the production of contemporaneous veins and pegmatites. When complementary rock magmas are erupted so close to one another in space and time that they come in conjunction while still highly heated, they may diffuse into one another, or blende to such an extent as to yield hybrid rocks, or mixed dikes, sheets, etc., as observed by Harker on the Isle of Skye.

The eruption of rock magmas through solid rocks and their solidification in various positions within or upon other rocks condition the modes of occurrence of igneous rocks, as those of lava streams, dikes, sheets, laccoliths, etc. And the parting or cracking of the solid rock, upon cooling, or its arrangement after fragmentation in various ways leads to distinctive structures, such as columnar, spheroidal or brecciated.

Having acquired a knowledge of the general principles applicable to all igneous rocks, it is in order to consider more specifically those occurring in all known parts of the world: first, systematically, according to some comprehensive scheme of arrangement, or classification, and then according to the groups, or associations, in which they occur in various regions, that is, according to petrographical provinces, or co-magmatic regions.

In order to describe many rocks a nomenclature is necessary, and the confusion existing in that in present use is best understood by considering the history of the growth of petrography, and the changes that have gone on in the definition and use of the oldest and commonest rock names, and descriptive terms. With this review should be associated a sketch of the development of rock classification, which has been furnished to the student in an interesting form by Cross.

A successful treatment of the subject of igneous rocks along the lines indicated would go far toward the removal of petrology from a state of distracting empiricism, and the placing of it on a more rational foundation.

JOSEPH P. IDDINGS
WASHINGTON, D. C.

CONDUCT OF SCIENTIFIC WORK UNDER THE UNITED STATES GOVERNMENT[1]

To the Senate and House of Representatives:

In compliance with the provisions of section 8 of the act of Congress making appropriations

[1] Message from the President of the United States, transmitting a report of the National Academy of Sciences relating to the conduct of the scientific work under the United States government.

for sundry civil expenses of the government for the fiscal year ending June 30, 1909, approved May 27, 1908, I transmit herewith for the consideration of the Congress the report of the National Academy of Sciences relating to the conduct of the scientific work under the United States government.

THEODORE ROOSEVELT

THE WHITE HOUSE,
January 18, 1909

NATIONAL ACADEMY OF SCIENCES,
OFFICE OF THE PRESIDENT,
Baltimore, January 16, 1909

Sir: The sundry civil act approved May 27, 1908, requests the National Academy of Sciences to consider certain questions relating to the conduct of the scientific work under the United States government, and to report the result of its investigations to Congress.

Immediately after the passage of the act a committee, consisting of five eminent men of science, none of whom held employment under the United States government, was appointed to make the necessary investigation. The members of that committee are:

R. S. Woodward, president of the Carnegie Institution of Washington, chairman.

W. W. Campbell, director of the Lick Observatory, Mount Hamilton, Cal.

Edward L. Nichols, professor of physics, Cornell University.

Arthur A. Noyes, acting president of the Massachusetts Institute of Technology.

Charles R. Van Hise, president of the University of Wisconsin.

Under date of January 9, 1909, this committee submitted its report to the council of the academy.

I have the honor to transmit herewith this report to Congress.

I am, sir, very respectfully,

IRA REMSEN,
President National Academy of Sciences

THE SPEAKER OF THE HOUSE
OF REPRESENTATIVES

REPORT OF COMMITTEE ON CONDUCT OF SCIENTIFIC WORK UNDER THE UNITED STATES GOVERNMENT

To the Council of the National Academy of Sciences:

During the first session of the Sixtieth Congress of the United States there was incorporated in the act making appropriations for sundry civil expenses of the government for the fiscal year ending June 30, 1909, the following section, namely:

SEC. 8. The National Academy of Sciences is required, at their next meeting, to take into consideration the methods and expenses of conducting all surveys of a scientific character and all chemical, testing and experimental laboratories and to report to Congress as soon thereafter as may be practicable a plan for consolidating such surveys, chemical, testing, and experimental laboratories so as to effectually prevent duplication of work and reduce expenditures without detriment to the public service.

It is the judgment of Congress that any person who holds employment under the United States, or who is employed by and receives a regular salary from any scientific bureau or institution that is required to report to Congress, should refrain from participation in the deliberations of said National Academy of Sciences on this subject and from voting on or joining in any recommendation hereunder.

In compliance with the terms of this legislation, the president of the National Academy of Sciences appointed the undersigned committee to consider the questions specified in said legislation, with a view of securing a report on or before the next annual meeting of the academy. This committee now has the honor to submit a report.

It should be explained, first, that in compliance with a request addressed by the president of the academy to the President of the United States, all of the executive departments of the government were directed to assist the representatives of the National Academy of Sciences in securing such information as might be necessary in preparing this report. The communication from the President of the United States announcing that such direction had been issued bears the date June 29, 1908. In conformity therewith numerous communications have been received by your committee from heads of departments and from bureaus and divisions of the government engaged in the kinds of work specified in the legislative act cited above.

In the second place, it should be stated that this committee has had access to the unpub-

lished preliminary report of a committee appointed by the President of the United States March 13, 1903, to consider many of the same questions here reported upon and others closely allied thereto. The chairman of the latter committee has also placed at our disposal a large mass of data collected by that committee.

In the third place, it should be stated that the members of your committee have been chosen in strict conformity with the requirements of the second paragraph of the legislative act quoted above.

A comprehensive interpretation of the functions of your committee shows that the field work for consideration is very large, and that it presents many difficulties requiring the most careful study before any final recommendations for legislative or executive action may be safely made. Nearly every department of the government is involved to a greater or less extent, while some departments, like the Department of Agriculture and that of Commerce and Labor, are carrying on scientific work in a great variety of ways. Thus, to illustrate the extent and variety of this work, it may be stated that surveys are now being carried on by seven different organizations under five different departments of the government; similarly, tests of apparatus, materials, foods, etc., are being made by the Bureau of Standards, by the technologic branch of the Geological Survey, by the Department of Agriculture, and to a minor degree by many other departments and bureaus of the government. Similarly, chemical work is carried on in many branches of the Department of Agriculture, by the Bureau of Standards, by the Geological Survey, by the Public Health and Marine-Hospital Service, and to a less extent by other branches of the public service.

It should be borne in mind also, in considering the present status of these organizations carrying on scientific work, that many of them have been so long established as to become integral parts of the departments to which they are assigned. Hence, any considerations looking to a consolidation or to a redistribution in the departments of these organizations should take into account their origin and historical development as well as their present status. The experience gained through a long series of years by these organizations should indicate what special merits they possess as well as the defects of organization and efficiency they may now present.

In view, therefore, of the importance of the scientific work now carried on by the government, and in view of the certain prospect that it will increase rather than decrease in the future, your committee is disposed to look at the problems presented by this work with a desire rather to furnish constructive criticism and advice than to recommend any immediate and radical changes based on destructive criticism, however well founded the latter may be in some cases. In other words, it appears more important to your committee to provide for enlightened and efficient conduct of governmental scientific work in the future than to be influenced to any considerable degree by the imperfections of organization and the inefficiencies in conduct of that work in the past.

From a general survey of the field of work under consideration three facts appear to be clearly established, namely:

First. That the amount of actual duplication of work now carried on by the government bureaus is relatively unimportant: but that the duplication of organizations and of plants for the conduct of such work is so considerable as to need careful attention from Congress in the future.

Second. That while the consolidation of some branches of work now carried on in several organizations is probably advisable, specific recommendations in reference to such consolidation can be made wisely only after a careful consideration of all the facts by the board hereinafter suggested or by some similarly competent body.

Third. That there has never been hitherto and there is not at present anything like a rational correlation of allied branches of scientific work carried on by the government.

This last fact appears to your committee by far the most important one presented for consideration. The lack of any well-defined plan for the development of such work, its distribution in various departments, and the lack of any systematic scheme of interrelations of the

bureaus carrying on this work have led inevitably and properly to the questions submitted by Congress to the academy.

It is plainly desirable, therefore, that Congress should make immediate provision to guard against a continuance of the evils which arise from a lack of any definite plan for, and from the absence of any adequate correlation of, the scientific work of the government.

It appears to your committee that the best way to deal with the condition now confronting the government is to secure the appointment by Congress of a permanent board which shall meet at stated intervals in each year for the consideration of all questions of the inauguration, the continuance, and the interrelations of the various branches of governmental scientific work. We would suggest that such a board should consist of the heads of bureaus carrying on scientific work, of two delegates from each of the Houses of Congress, and of five to seven eminent men of science not connected with the government service.

By means of a few meetings per year, with authorization to secure the requisite information from the heads of departments and bureaus concerned, all of the complicated questions which now are at best only ill considered could be carefully determined with great advantage in point of economy and efficiency to the public service and with little or no additional expense thereto.

Such a board could take under consideration the prevailing lack of system and lack of correlation in the work in question and gradually remove these defects from existing bureaus and divisions of the public service. All questions of the assignment, of the conduct, of advisable consolidation, and of the economies of such work could be fully discussed and determined in the best interests of the government by such a board. If the heads of bureaus and divisions were required to submit their projects and estimates for work to this board before transmission to the heads of departments and to Congress, all questions of the duplication of work, of the duplication of organizations, of the duplication of laboratories or equipments, and of the most economical assignment could be readily determined without interference in the details of management of the organizations concerned.

One of the most important functions of such a board should be that of the nomination or selection of men competent to take charge of new projects or to fill vacancies which may arise in the more important positions of the scientific work in question. It would thus be generally possible to prevent the assignment of an incompetent man to the charge of a highly technical or specialized branch of the public service. It would thus be possible also to secure men of the highest professional attainments and to prevent the calamity which has not infrequently occurred in the past of assigning important scientific work to unprofessional or incompetent men. It would thus be possible likewise to take advantage of the competition between different branches of the public service in the laudable desire of those branches to prove their efficiency by the accomplishment of the required work of the government in the best and most economical ways.

Very respectfully submitted.

R. S. Woodward,
Chairman,
W. W. Campbell,
Edward L. Nichols,
Arthur A. Noyes,
Charles R. Van Hise

Washington, D. C.,
January 9, 1909

RECENT WORK OF THE MOUNT WILSON SOLAR OBSERVATORY

Monochromatic photographs of the sun have been made daily on Mount Wilson since October, 1905, with the Snow telescope and five-foot spectroheliograph. The weather has been very favorable, permitting calcium, hydrogen and frequently iron images to be taken on 303 days in 1908, and on 113 consecutive days during the summer of 1907. Prior to March, 1908, the hydrogen photographs were made with the light of the violet line $H\delta$. Since that time, with the aid of plates sensitized by Wallace's formula, excellent results have been obtained with the red hydrogen line $H\alpha$. These record the phenomena of a region in the solar atmosphere higher than that previously

explored, and reveal the existence of extensive vortices or cyclonic storms associated with sun-spots. In general, the direction of rotation of the vortices is counter-clockwise in the northern hemisphere and clockwise in the southern, as in the case of terrestrial cyclones; but a few interesting exceptions, in which the direction of rotation was reversed, have been found. There can now be little doubt that what we see in the telescope as a sun-spot is the mass of vapor, cooled somewhat below the temperature of the photosphere, which lies at the center of an invisible vortex (*Astrophysical Journal,* Vol. XXVIII., pp. 100–16).

The discovery of these vortices suggested that the rapid revolution of electrically charged particles, emitted from carbon and other vapors at the high temperature of the sun, should produce a magnetic field in sun-spots. Tests made with the 30-foot spectrograph of the tower telescope show all the characteristic phenomena of the Zeeman effect in the spot spectrum, and leave no doubt as to the existence of a magnetic field. The strength of the field has been found to range from about 2,800 to about 4,500 gausses in different spots. Vortices rotating in opposite directions show opposite polarities, the changes in the spectrum and in the polarization phenomena being precisely similar to those of a luminous source in a magnetic field when the current through the magnet is reversed. The results indicate that the magnetic field is produced by the revolution of negative corpuscles in the vortices (see *Astrophysical Journal,* Vol. XXVIII., pp. 315–343). There is some evidence that the plane of polarization of light passing through the spot vapors is rotated through different angles in different parts of the umbra, but more observations of this phenomenon are needed. For this and other purposes a tower telescope 160 feet high, giving a solar image 16 inches in diameter, and a spectrograph 75 feet long, mounted in a well below the tower, should prove of the greatest service. These instruments are now being designed, and will soon be constructed in our Pasadena shop.[1]

[1] This telescope, of small aperture (12 inches) and great focal length (150 feet), is designed exclusively for work on the sun, where a large image is required. The 60-inch and 100-inch reflecting telescopes, of great aperture and smaller focal length, are not suitable for solar observations, but will be used for the study of stars and nebulæ.

The above results are of some general interest, since they conclusively demonstrate for the first time the operation of electric phenomena in the sun. So far as the cause and nature of sun-spots are concerned, they seem to favor Emden's theory. An attempt is now being made to determine whether the sun as a whole is a magnet. The tests already completed indicate that extremely sensitive methods will be required to settle the question, and these will soon be applied.

The 60-inch reflecting telescope, which has been under construction in our instrument and optical shops during the last four years, is now in operation on Mount Wilson. Visual and photographic tests show this instrument to be of the highest optical and mechanical perfection, and reflect great credit upon Professor Ritchey, its designer, and those who have been associated with him in the extensive work of construction and erection. Photographs of nebulæ made by Professor Ritchey, and a series of photographs of the great nebula in Orion, made through a red screen by the writer, are of exquisite sharpness and perfection of detail. The star images are extremely small, and the wealth of faint stars shown leaves no doubt that in light-grasping power, as well as in optical resolution, the telescope will meet our highest expectations. One of the most gratifying results of these tests is the proof they afford of the excellence of the night conditions on Mount Wilson. For the last four consecutive nights (January 16, 17, 18, 19) the definition with the full aperture of 60 inches has been essentially perfect from a photographic standpoint. This is in the midst of the rainy season, when the atmosphere is far less steady than during the unbroken succession of clear days and nights of summer. A telescope of 100 inches aperture, or even larger, could certainly be used here to great advantage on nights such as we have already tested. Fortunately, Mr. John D. Hooker, of Los Angeles, has agreed to meet the expense

of constructing a large mirror for this observatory. A disk of glass 100 inches in diameter and 13 inches thick, weighing 4½ tons, has recently been received at our Pasadena shop from the French Plate Glass Works at St. Gobain, France. Much time was consumed in filling our order, and it was hoped that the disk would prove suitable. This does not turn out to be the case, however, and another trial must be made. The observatory will experience no financial loss, as the disk had not been accepted. The loss in time will not be very serious, because of the great opportunities for research in unexplored fields afforded by the 60-inch reflector. I have no doubt that the difficulties of making a homogeneous disk of these great dimensions will soon be successfully overcome, and that the Hooker telescope will be ready in time to extend the work of the 60-inch reflector into territory which even this powerful instrument can not enter.

George E. Hale

BROOKS MEMORIAL

In the Donovan room of McCoy Hall, Johns Hopkins University, the end of the old and beginning of the new year saw a memorable reunion of men who had worked in contact with Professor W. K. Brooks. Under the guidance of the chairman, Professor S. F. Clarke, many paid tribute to Brooks, the inspiring teacher, whose life at Williams and at Cambridge was vividly sketched by Professor Edward A. Birge, and whose career at the Johns Hopkins furnished the material for many pleasant recollections and expressions of esteem and of love by Professors E. B. Wilson, H. W. Conn, H. H. Donaldson, F. H. Herrick, M. M. Metcalf and others who were Brooks's pupils in later years.

Upon motion of Professor Harrison a committee was appointed to prepare a memorial volume in honor of their master.

Professor E. L. Mark and thirty-two other zoologists of Harvard, in attendance upon the scientific meetings in Baltimore, wrote to express their "sentiments of highest appreciation for the character of the work of William Keith Brooks."

It was hoped that the incidents of Professor Brooks's life at Penikese could be made vivid by one who was there with Brooks, but a telegram from President David Starr Jordan stated his regret that he could not be present to honor the memory of "the wisest of American naturalists." Others were also unable to come to Baltimore. The names of the sixty men actually present follows below:

Edward A. Birge, fellow student at Williams College, professor of zoology, University of Wisconsin.

Samuel Fessenden Clarke, Ph.D., 1874, professor of natural history, Williams College.

Edmund Beecher Wilson, Ph.D., 1881, professor of zoology, Columbia University.

Albert H. Tuttle, professor of biology, University of Virginia.

Basil Sollers, student, 1878–9, teacher in public schools, Baltimore.

William Henry Howell, Ph.D., 1884, professor of physiology, Johns Hopkins University.

Herbert William Conn, Ph.D., 1884, professor of biology, Wesleyan University.

Henry Herbert Donaldson, Ph.D., 1885, professor of neurology, University of Pennsylvania.

Frederick Schiller Lee, Ph.D., 1885, professor of physiology, Columbia University.

James Playfair McMurrich, Ph.D., 1885, professor of anatomy, University of Toronto.

Albro David Morrill, Beaufort Laboratory, 1885, professor of biology, Hamilton College.

George Theophilus Kemp, Ph.D., 1886, sometime professor of physiology, University of Illinois.

Louis J. Rettger, student, 1886–9, candidate for Ph.D., 1909, professor of physiology, Indiana State Normal School.

Charles L. Edwards, graduate student, 1886–9, professor of natural history, Trinity College.

F. L. Washburn, graduate student, 1886–7, state entomologist, Minnesota, and professor of entomology, University of Minnesota.

Edwin Linton, Beaufort, Laboratory, professor of zoology, Washington and Jefferson College.

Ethan Allen Andrews, Ph.D., 1887, professor of zoology, Johns Hopkins University.

Henry Gustav Beyer, Ph.D., 1887, medical inspector, United States Navy.

John Pendleton Campbell, Ph.D., 1888, professor of biology, University of Georgia.

Francis Hobart Herrick, Ph.D., 1888, professor of biology, Adelbert College.

Henry Van Peters Wilson, Ph.D., 1888, professor of biology, University of North Carolina.

Arthur Lincoln Lamb, A.B., 1888, science master, Country School, Baltimore.

Clifton Fremont Hodge, Ph.D., 1889, assistant professor of physiology, Clark University.

Thomas Hunt Morgan, Ph.D., 1890, professor of experimental zoology, Columbia University.

Henry Torsey Fernald, Ph.D., 1890, professor of entomology, Massachusetts Agricultural College.

Edwin Grant Conklin, Ph.D., 1891, professor of zoology, Princeton University.

Robert Payne Bigelow, Ph.D., 1892, instructor in biology and librarian, Massachusetts Institute of Technology.

George Wilton Field, Ph.D., 1892, zoologist, Massachusetts Board of Fisheries.

Theodore Hough, Ph.D., 1893, professor of physiology, University of Virginia.

Maynard Mayo Metcalf, Ph.D., 1893, professor of zoology, Oberlin College.

Herbert Spencer Jennings, professor of experimental zoology, Johns Hopkins University.

Ross Granville Harrison, Ph.D., 1894, professor of comparative anatomy, Yale University.

Reid Hunt, Ph.D., 1896, pharmacologist, Bureau of Health, Washington, D. C.

Henry McElderry Knower, Ph.D., 1896, associate in anatomy, Johns Hopkins University.

George Lefevre, Ph.D., 1896, professor of zoology, University of Missouri.

Hubert Lyman Clark, Ph.D., 1897, assistant in invertebrate zoology, Harvard University.

Charles Peter Sigerfoos, Ph.D., 1897, professor of zoology, University of Minnesota.

Duncan Starr Johnson, Ph.D., 1897, professor of botany, Johns Hopkins University.

Gilman Arthur Drew, Ph.D., 1898, professor of biology, University of Maine.

Caswell Grave, Ph.D., 1899, associate professor of zoology, Johns Hopkins University.

Albert Moore Reese, Ph.D., 1900, professor of zoology, West Virginia University.

William Chambers Coker, Ph.D., 1901, associate professor of botany, University of North Carolina.

Henry Farnham Perkins, Ph.D., 1902, assistant professor of zoology, University of Vermont.

Lewis Robinson Cary, student, 1903–5, holder of fellowship, Princeton University.

Rheinart Parker Cowles, Ph.D., 1904, instructor in biology, Johns Hopkins University.

Otto Charles Glaser, Ph.D., 1904, instructor in zoology, University of Michigan.

David Hill Tennent, Ph.D., 1904, associate professor in zoology, Bryn Mawr College.

Eugene Willis Gudger, Ph.D., 1905, professor of biology and geology, North Carolina Normal and Industrial College.

John Augustine English Eyster, M.D., 1905, associate professor of physiology, University of Virginia.

Samuel Rittenhouse, Ph.D., 1905, instructor in biology, Olivet College.

Robert Irvine Coker, Ph.D., 1906, special investigator for Peruvian Government.

Bartgis McGlone, Ph.D., 1907, professor of biology, St. John's College.

Ivey Foreman Lewis, Ph.D., 1908, professor of biology, Randolph-Macon College.

William E. Kellicott, lecturer, 1908, professor of biology, Woman's College, Baltimore.

Samuel Ottmar Mast, Johnston scholar, 1907–8, associate professor of biology, Woman's College.

J. Frank Daniel, Adam T. Bruce, fellow, 1908–9, Johns Hopkins University.

William Dana Hoyt, fellow in botany, 1908–9, Johns Hopkins University.

Asa Arthur Schaeffer, fellow in zoology, 1908–9, Johns Hopkins University.

Frederick Harvey Blodgett, candidate for Ph.D., 1910, Johns Hopkins University.

William Henry Brown, candidate for Ph.D., 1910, Johns Hopkins University.

SCIENTIFIC NOTES AND NEWS

As has already been announced, Sir J. J. Thomson, F.R.S., will preside over the Winnipeg meeting of the British Association to be held from August 25 to September 1 of this year. The presidents of the sections are as follows: A (Mathematical and Physical Science), Professor E. Rutherford, F.R.S.; B (Chemistry), Professor H. E. Armstrong, F.R.S.; C (Geology), Dr. A. Smith Woodward, F.R.S.; D (Zoology), Dr. A. E. Shipley, F.R.S.; E (Geography), Sir Duncan A. Johnston, K.C.M.G.; F (Economic Science and Statistics), Professor S. J. Chapman; G (Engineering), Sir William H. White, K.C.B., F.R.S.; H (Anthropology), Professor J. L. Myres; I (Physiology), Professor E. H. Starling, F.R.S.; K (Botany), Lieut.-Colonel D. Prain, F.R.S.; L (Educational Science), Dr. H. B. Gray; and subsection, Agriculture, Major P. G. Craigie (chairman).

MR. H. B. WOODWARD, F.R.S., having reached the age of seventy-six years, has re-

tired from the assistant directorship of the Geological Survey of Great Britain. He is succeeded by Dr. H. Strahan, F.R.S.

M. Léon l'Abbé, who has recently been re-elected to the French senate, succeeds M. Bucquosy as president of the Paris Academy of Medicine.

Mr. Arthur Silva White has resigned as assistant secretary of the British Association for the Advancement of Science.

Professor Hillhouse will retire from the chair of botany in the University of Birmingham at the end of the present session.

Mr. R. James Wallace, who has for several years past been engaged in photographic research at the Yerkes Observatory, as instructor in photophysics, has resigned his position there to become director of the research laboratory of the Cramer Dry Plate Company at St. Louis. It is a promising evidence of appreciation of research that a commercial company engages the services of a scientific investigator for the improvement and further development of its products.

The Geological Society of London will this year award its medals and funds as follows: Wollaston medal, Mr. Horace B. Woodward, F.R.S.; Murchison medal, Professor Grenville A. J. Cole; Lyell medal, Professor Percy F. Kendall; Bigsby medal, Dr. John Smith Flett; Prestwich medal, Lady Evans; Wollaston fund, Mr. Arthur J. C. Molyneux; Murchison fund, Mr. James V. Elsden; Lyell fund, Mr. R. G. Carruthers and Mr. Herbert Brantwood Muff.

Dr. John M. Coulter, head of the department of botany in the University of Chicago, was among those who returned to New York on the *Baltic* after the ill-fated trip of the steamer *Republic*.

We learn from *Nature* that Professor J. Arthur Thomson, of Aberdeen University, has been invited by the lecture committee of the South African Association for the Advancement of Science to give the "South African Lectures" for 1909. The lectures are to be delivered in August and September in Johannesburg, Pretoria, Bloemfontein, Kimberley, Cape Town, Grahamstown and Durban, and at the request of the committee they will have special reference to the Darwin centenary.

Mr. G. W. Bury has undertaken an expedition into southwest Arabia.

Mr. Donald Mackay is engaged in exploration in British New Guinea. He is attempting to ascend the Purari River, with a view to making his way overland to the head waters of the Fly River.

Dr. C. W. A. Veditz, professor of economics at George Washington University, has been selected as a special expert agent for the United States Department of Labor and Commerce to investigate the child-labor problem and conditions in the principal industrial countries of Europe. He will leave this country on February 3 and will remain abroad for about eight months.

President Roosevelt has appointed Mr. W. K. Moorehead, curator of archeology in Phillips Academy, Andover, a member of the United States Board of Indian Commissioners.

Dr. Francis E. Fremantle, medical officer of health for Hertfordshire, has been appointed to the Edward Jenner lectureship in public health at St. George's Hospital Medical School, London.

Under the auspices of the Pennsylvania Society of the Archeological Institute of America, a public lecture was given at the University of Pennsylvania Museum on Wednesday afternoon, January 27, on "Excavations and Repairs at Casa Grande, Arizona," by Professor J. Walter Fewkes, of the U. S. Bureau of American Ethnology.

Mr. Fred G. Plummer, chief of geography in the National Forest Service, gave a lecture on "The American Forests" before the department of geology of Colgate University, on the evening of January 20.

At the regular meeting of the Academy of Science of St. Louis, held on January 18, 1909, with Professor Wm. Trelease presiding, Professor W. H. Roever, of the department of mathematics of Washington University, presented a paper embodying his researches on

"An Optical Interpretation of some Problems in Statistics."

AT the meeting of the Royal Microscopical Society on January 20, Lord Avebury delivered his presidential address on seeds, with special reference to British plants.

PROFESSOR KARL PEARSON gave last month before the Royal Institution of Great Britain two lectures on "Albinism in Man."

SIR THOMAS WARDELL, known for his researches on silk fiber, died on January 3, in his seventy-eighth year.

MAJOR PERCY B. MOLESWORTH, who had made valuable observations on Jupiter and Mars, died in Ceylon on December 26, in his forty-second year.

M. DOMINIQUE CLOS, honorary professor of botany at Toulouse, has died at the age of eighty-eight years.

THE House of Representatives has included in the military appropriation bill an appropriation of $500,000 for air-ships. The Russian war office has reserved for this purpose a fund of $750,000. The Aero Club of America offers a prize of $10,000 for a race from New York City to Albany as part of the Hudson-Fulton memorial celebrations to be held in the autumn.

THE sum of $100,000 has been given to the medical school of the London Hospital, the income to be expended in the advancement of medical research and the promotion of higher education in medicine.

BARON BESSIÈRES has left a legacy of $16,000 to the Pasteur Institute, Paris, to be employed in scientific researches.

A ROYAL BRITISH RADIUM INSTITUTE is to be established through a gift from Sir Ernest Cassel. It is intended to investigate especially the therapeutic action of radium. In this connection it is reported that a syndicate has been formed in connection with the institute to extract radium from the pitch-blend deposits of an old copper mine recently reopened at St. Ives, Cornwall. This is said to be the only place where radium can be produced outside of Austria.

A SOCIETY of radiology has been founded in Paris for the scientific study of the medical applications of radiations in general.

THE important George G. Heye collection of American antiquities will soon be placed on exhibition in the Museum of the University of Pennsylvania.

Two additions to the series of North American habitat groups in the American Museum of Natural History have recently been completed. These are the Duck Hawk group, representing a scene along the Palisades of the Hudson River, and the Hackensack Meadow group, which represents the nesting habits of the birds which frequent it in August.

A MEDICAL congress is to be held in Bombay, beginning on February 22. Sir George Clarke will deliver the presidential address, and the sectional meetings will last four days.

ARRANGEMENTS for the North American Conservation Conference between representatives of the United States, Canada and Mexico, at the White House, February 18, are going forward rapidly, following the cordial acceptance by Sir Wilfrid Laurier, Premier, and Earl Grey, Governor-General, of Canada, and President Diaz, of Mexico, of President Roosevelt's invitation to send delegates. The conference will discuss the situation with regard to the natural resources of the respective countries and help prepare a general plan adapted to promote the welfare of the nations concerned in accordance with President Roosevelt's suggestion. This International Conference will meet at the White House by President Roosevelt's invitation. It will not be a large gathering as was the Conference of Governors at the White House last May, or the joint Conservation Conference last December between the National Conservation Commission, the Governors and the representatives of State Conservation Commissions and Conservation Committees of national organizations. The attendance will be limited to the representatives of Canada and Mexico and representatives of the State Department of the United States Government and of other executive departments which can render particular assistance to the conferees in their deliberations,

and the National Conservation Commission. Canada has already taken active steps in preparation for the conference and recently sent to the National Conservation Commission a number of carefully prepared maps which show the present status of the public lands of the dominion as well as the distribution of the principal natural resources and the development of its transportation systems. The Canadian authorities have also gathered together and sent to the chairman of the commission a comprehensive collection of government documents bearing on the natural resources of the country. These have been carefully indexed and bound together according to subjects. They will be used at the forthcoming conference.

Mr. D. C. Sowers, in charge of the special magnetic expedition to China under the auspices of the Carnegie Institution of Washington, left Peking on January 30. He will be assisted by Professor Chester G. Fuson, for the past four years professor of history and geography at the Canton Christian College. The general route to be followed by the party will touch at the following places: Sianfu, Lanchowfu, Suchow, Turfan, Kashgar, Khotan, thence, via the Karakorum Pass, into India, where connection will be made at Dehra Dun with the magnetic survey of India. A series of magnetic observations will, therefore, be obtained in parts of China and Chinese Turkestan where no previous data existed. Dr. J. C. Beattie, director of the department of physics, South African College, Cape Town, has been granted a year's furlough in order to take charge of a magnetic survey party under the auspices of the Carnegie Institution of Washington. He left Cape Town November 25. His general route of travel will be through German Southwest Africa, thence into Rhodesia, British East Africa, German East Africa, and next through Nubia and Egypt, connecting with the magnetic survey of Egypt at Cairo. He will be assisted by Professor J. T. Morrison, in charge of the department of physics, Victoria College, Stellenbosch, South Africa, who will confine his work chiefly to points reached by steamer along the east and west coasts of Africa. There will thus be obtained during the present year magnetic data in regions of Africa hitherto almost entirely unexplored. Mr. Joseph C. Pearson, who during the past year has been engaged in making magnetic observations in various parts of Persia under the auspices of the Carnegie Institution, will be ready to undertake similar work in Asia Minor, beginning at Bagdad some time in March.

Prizes conferred by the Paris Academy of Medicine include: the Baillarger prize (£80) to Dr. A. Rodiet, of Dun-sur-Auron, for a contribution to the study of the organization of lunatic asylums; the Barbier prize (£80) has been divided among several competitors, Dr. P. Remlinger, of Constantinople, getting £32 for a series of researches on rabies, Dr. L. Malloizel, of Paris, £24 for anatomo-clinical researches on pleuro-cortical reactions, and Drs. Louis Wickham and Degrais, of Paris, a like amount for their work on the treatment of angiomas of radium. To Professor Calmette, director of the Pasteur Institute at Lille, and MM. Boullanger and E. Rolants, heads of laboratories, F. Constant and L. Massol, demonstrators in the same institute, and Professor Buisine, of the Lille Faculty of Science, has been awarded the Orfila prize (£160) for researches on the purification of water that has been used in towns and of the residual water of factories. Dr. Marfan has won the Roger prize (£100) for his treatise on suckling and the feeding of infants. The Saintour prize (£176) has been awarded to Dr. Emile Sergent, of Paris, for his work on syphilis and tuberculosis; the Campbell-Dupierris prize (£92) to Dr. Morris Nicloux, *Professeur agrégé* of the Paris Faculty, for his work on general anesthetics from the chemico-physiological point of view. The Ernest Godard prize (£40) has been awarded to Dr. F. W. Pavy, of London, for his work on carbohydrates and their transformation—a physiologico-pathological study with considerations on diabetes and its treatment.

The New York State Bar Association at the closing session of its thirty-second annual meeting at Buffalo on January 29, went on

record in favor of a bill designed to correct the evils of expert medical testimony in the courts. The draft of the bill provides, among other things, that "in criminal cases for homicide where the issues involve expert knowledge or opinion the court shall appoint one or more suitable disinterested persons, not exceeding three, to investigate such issues and testify at the trial; and the compensation of such person or persons shall be fixed by the court and paid by the county where indictment was found, and the fact that such witness or witnesses have been so appointed shall be made known to the jury. This provision shall not preclude either prosecution or defense from using other expert witnesses at the trial."

UNIVERSITY AND EDUCATIONAL NEWS

A BILL has been introduced in the Wisconsin legislature which proposes to increase the building fund of the University of Wisconsin from $200,000 to $300,000 annually, and to lengthen the period of this appropriation from five to seven years.

A NEW industrial fellowship has been presented to the University of Kansas by the Holophane Glass Co. It yields $1,500 a year for two years, together with ten per cent. of the profits that may arise from any discoveries made by the student who pursues the special study. The fellowship is open to students of any university, but the work will be done in the laboratories of the University of Kansas.

BRYN MAWR COLLEGE has established ten graduate scholarships, five open to English, Irish or Scotch and five to German women students, who have attained a standard equivalent to that of the bachelor's degree. The scholarship covers the fees for board, residence and tuition at Bryn Mawr College for one academic year and as these fees for graduate students amount to $405 this is equivalent to a scholarship of £81 or of 1,620 Marks.

MR. CHINUBHAI MADHOWLAL has given four lakhs of rupees (about $125,000) to be applied by the Bombay Government towards the development of science teaching in Ahmedabad, in connection, if possible, with the proposed Curline Institute in Bombay.

THE University of Liverpool has received an offer from Mr. Alexander Elder, to contribute $50,000 for the establishment of a chair of naval architecture.

ON recommendation of the faculty of the medical department of Western Reserve University, the trustees have voted that beginning with the academic year 1910–11 the requirement for unconditional entrance to the medical department shall be graduation from an approved college or scientific school granting the bachelor's degree (or equivalent) following the completion of a course of at least three collegiate years and including inorganic chemistry, physics, biology and Latin. Conditional entrance will be granted upon the completion of the work of the junior year in the course of an approved college or scientific school enforcing a four-year course (or equivalent degree) including the subject requirements enumerated above, conditioned upon the student obtaining a baccalaureate degree before he enters the third year in the medical school.

DR. A. GRAHAM LUSK, professor of physiology at the University and Bellevue Hospital Medical School has been appointed professor of physiology in the Cornell Medical College.

DR. DANA B. CASTEEL, instructor in zoology in the University of Michigan, has been appointed instructor in zoology in the University of Texas.

CAPTAIN H. G. LYONS, F.R.S., director-general of the survey of Egypt, has been appointed lecturer in geography at the University of Glasgow.

DISCUSSION AND CORRESPONDENCE

THE LAW OF RADIATION

TO THE EDITOR OF SCIENCE: Is it worth while to keep on upholding certain theories, and to wholly neglect certain new facts which tend to undermine the very foundation on which these theories rest? What justification

is there, for instance, in declaring that my "definition for temperature"[1] is erroneous without an accompanying proof showing that Newton's law of radiation is also erroneous? As this particular matter stands, Dr. Reid has simply made a dogmatic assertion, for if Newton's law is true (and I claim to have demonstrated that it is true) it follows as a theoretical necessity that *absolute temperature is a direct measure of the intensity of ether vibration.* If Stefan's law, or any other law except Newton's, can be demonstrated to be true, then, and then only, will scientists be justified in summarily condemning my conclusions.

J. M. Schaeberle

Ann Arbor, Mich.,
January 4, 1909

American Scientific Productivity

It is well that we should be reminded by Professor Nichols in his presidential address before the American Association (Science, January 1, 1909) and by Professor Pickering in his articles in *The Popular Science Monthly* (October, 1908, and January, 1909) that the scientific work accomplished in this country is not commensurate with its population and its wealth, and that Professor Willcox (Science, January 29, 1909) should reinforce this fact from the awards of the Nobel prizes.

But while we can not too strongly emphasize the circumstance that we are not doing all that we should for the advancement of science and that this is partly due to the fact that the scientific career is not made sufficiently attractive to obtain and retain the best men, nor sufficiently free to enable them to do their best work, it yet seems that the situation is by no means discouraging. The articles mentioned measure our scientific productivity by the eminent men we have. In so far as this is an adequate method, it tends to measure our activity a generation ago; for men do not usually obtain international recognition until long after the work for which it is given has been accomplished.

Professor Pickering finds that of the 87 scientific men who are members of at least two foreign academies only six are Americans. Each of the two eminent American men of science who is a member of the largest number of academies is in his seventy-third year. It is a striking fact that of the six distinguished Americans, three are astronomers; and astronomy is the only science in which thirty years ago the facilities for research work in this country were equal to those of the leading European nations. Of the remaining three, two have not been engaged in teaching, and the third has been practically freed from teaching for his research work. We may have, in accordance with Professor Pickering's data, but six scientific men as distinguished as 17 in Prussia, 13 in England and 12 in France, but this would represent the relative scientific activity of the country at the time when our universities were only beginning to develop and when research work under the government was only beginning.

The Nobel prizes have, contrary to the instructions of the founder, been, as a rule, awarded to eminent men for work done in the past; and the fact that of twenty-four prizes in the sciences only one has come to America does not discredit our present scientific research. If the provision of Nobel's will had been followed and the prize had been given to the person "rendering the greatest service to humanity," by "having made the most important discovery or invention in the department of physical science," the first two awards should probably have been to Mr. Bell and Mr. Edison.

It is a curious fact that the three subjects in which the Nobel prizes are awarded—physical science, chemistry and medicine—are those in which we are particularly weak. These are the sciences in which the applications are the most direct, and it looks as if those competent to advance these sciences had been carried into practical work. This is contrary to my preconceptions, for I should suppose that when there are large opportunities for practical work, there should also be advances in pure science. Perhaps it is only individual eminence that is here lacking, and we are in fact contributing our share to

[1] Science, January 1, 1909, p. 29.

The choir invisible
Whose music is the gladness of the world.

We seem to do better in the natural sciences. In geology, zoology, botany, anthropology and psychology, there is probably more research work published here than in any other country except the German empire and the amount of research work published is the most tangible, and perhaps the most exact, measure of scientific activity. I have found that in the *Zeitschrift für Psychologie* there have been more articles in experimental psychology reviewed (selected as the more important articles) from America than from the German-speaking nations combined, and more than ten times as many as from Great Britain. We have also, according to the criterion of membership in foreign academies, the most eminent living psychologist.

The statement made by Professor Nichols and endorsed by Professor Willcox that "the men who have laid the foundations upon which civilization is built have nearly all been teachers and professors" appears to be more correct for Germany than for England. Darwin did not teach, and not one of the five scientific members of the Order of Merit—Hooker, Huggins, Lister, Rayleigh and Wallace—is a teacher. It is a remarkable fact that while Germany has excelled in the quantity of research work accomplished since the development of its universities, England has produced the greatest leaders. The elementary teaching required in our collegiate universities not only absorbs time and energy, but also tends to develop a superficial omniscience and a dogmatic attitude unfavorable to investigation. If we add to this the clerical, administrative and missionary work, which the university president crowds on the university professor, and the distracting need of earning enough money to support his family, there is perhaps reason to wonder that he accomplishes as much research work as he does accomplish.

Fortunately there has been within thirty years a great increase in this country in the number of positions permitting scientific work, and in the opportunities which these positions offer for research work. Many of our universities have admirable laboratories, and there is certainly a strong sentiment in favor of permitting the professors to use them. We are gradually obtaining university laboratories analogous to the astronomical observatories, where professors will only do so much teaching as is favorable to their investigations. At the same time there has been a notable development of scientific work outside the universities, under the national government, under states and municipalities, in technological work, and recently in the establishment of research institutions such as the Carnegie Institution of Washington and the Rockefeller Institute for Medical Research. The material foundation is already adequate and will be rapidly enlarged. What we need is more men with the ability and spirit which research work demands.

J. MCKEEN CATTELL

SCIENTIFIC BOOKS

Qualitative Analyse vom Standpunkte der Ionenlehre. Von Dr. WILHELM BÖTTGER, Privatdozent und Oberassistent am Phys.-Chem. Institut der Universität Leipzig. Zweite, Umgearbeitete und Stark Erweitete Auflage. Leipzig, Wilhelm Engelmann. 1908.

The first edition of this book was published in 1902. An English translation by Smeaton appeared in 1906, a book of 300 pages. This second German edition is a stately volume of 524 pages; it contains nearly double as much matter as its predecessor and is quite different in arrangement.

The fundamental general and ionic theory is in a division by itself, forming the first 116 pages of the book, and is illustrated by simple but ingenious and instructive experiments, thirty-five in number. These experiments alone would give the book permanent value, but it is worthy of study throughout.

In the chapter on systematic analysis, for example, a method is given, familiar in detail but new in application, for separating the cations of group III.; after treatment of the sulphides with dilute HCl, and filtering, the filtrate containing Al, Cr. Fe, Mn, Zn and

traces of Co and Ni, is heated to drive off H_2S, and cooled; it is then treated with an excess of KOH, oxidized with Br water or H_2O_2, and filtered. The residue may contain $Fe(OH)_3$, MnO_2H_2, and traces of $Cr(OH)_3$, $Co(OH)_3$, $Ni(OH)_3$. The filtrate may contain K_2CrO_4, AlO_2K, and ZnO_2K_2. The Cr is tested for by oxidizing an acidulated portion of the filtrate to perchromic acid by H_2O_2. Another portion of the filtrate is exactly acidulated with HCl, and precipitated by sodium acetate as aluminium basic acetate, thus securing the detection of very small amounts of Al. The filtrate from the oxyacetate contains the Zn which is precipitated as sulphide by H_2S. Iron and manganese are tested for by dissolving one portion of the residue in HCl, and adding KCNS, or $Fe(CN)_6K_4$, and by fusing another portion of the residue with $Na_2CO_3 + KNO_3$. The presence of traces of compounds of Cr, Co, Ni, not interfering with these tests. This method will be found simpler, shorter, and fully as accurate as the barium carbonate method, which is so generally recommended, when Cr, Mn and Fe are all present in the substance analyzed.

In the chapter on solutions the treatment of sulphides and chlorides insoluble in acids is noticeable.

In the chapter on preliminary treatment the introduction of the Hempel reduction methods is praiseworthy.

The phase-rule is entirely omitted; just why it is hard to see. One may say that beginners can not understand it, but this is not a book for beginners. However, as Dr. Böttger is chief assistant in the Leipsic laboratory, he must be credited with due consideration of the theories to be introduced or omitted.

Elementary physical chemistry throws such a flood of light on the problems of analysis that the opponents of its use for this purpose are fewer every year; although among the new manuals are some which practically differ from the older books only in adding the word "ion" to the name of the element, and freely using + and — signs; such books do not illuminate and make no converts.

The present book, it is true, is too large and too detailed for American college students, but any one who intends to write a laboratory manual—and who does not write one?—will do well to read Dr. Böttger's book carefully.

It would be well if the author should arrange with his American translator to publish an abbreviation of this book for college use, containing the theoretical part and experiments without change, but cutting down the remainder to a third of its present size. This is practicable, as much of the present material should be omitted for college use, and as Dr. Böttger's German is extremely diffuse. Such a book would be very valuable for college students in their second laboratory-year.

The book, as it is, should be studied by graduate students, and especially by teachers, who will find in its pages simple explanations of more than one puzzling phenomenon. It is to be hoped that the book will meet with the recognition which it merits.

E. Renouf

A Treatise on Chemistry. By H. E. Roscoe and C. Schorlemmer. Volume II.: The Metals. New Edition, completely revised by H. E. Roscoe and A. Harden. Pp. xii + 1436. New York, The Macmillan Company.

Sir Henry Roscoe is to be congratulated most heartily on the revision of the well-known "Treatise on Chemistry." It is seldom that an author lives to see such an extensive work useful through thirty years and at the end of that time appear entirely fresh with all of the most recent developments in theory and application. The book bears the strong personal impress of the author and is delightful reading on account of the intimate historical presentation of the various subjects. The scientific, practical and historical are so nicely interwoven as to make the book most readable and valuable.

The introduction of material on Werner's valence theory, the phase rule, radio-activity, Thomson's corpuscular theory and other recent developments has added much to the value of the book. In addition to these an account of recent work on alloys has been added, although the treatment is not entirely satisfac-

tory. The brief reference to such an important subject as the constitution of steel is to be regretted.

The subject of crystallography, which was formerly given in the volume of the non-metals, has been transferred to this volume and occupies fifty pages. It is fully believed that such special subjects as this and spectrum analysis (25 pages) might be condensed into much smaller space without injuring the value of the book.

The metallurgical and technical processes, as in previous editions, have been satisfactorily treated, and have been brought up to date.

While the chemists will be pleased to have so excellent a statement of his science as this book, he will regret that the author has not drawn more largely from his long experience and given more attention to criticism and generalization.

HENRY FAY

Lead and Zinc in the United States, Comprising an Economic History of the Mining and Smelting of the Metals, and the Conditions which have affected the Development of the Industries. By WALTER RENTON INGALLS. Pp. x + 368, illustrated. New York, Hill Publishing Co. 1908. $4.

Most publications dealing with the histories of metals have mainly an antiquarian interest. The two leading exceptions to this general rule are found in the great work of Beck on iron, and the more general book of Neumann on the leading industrial metals, as both authors have taken up the statistical, industrial and technical sides, and added them to the usual chronological treatment of the subject.

The present work deals with lead and zinc only, the ores of which frequently occur together and therefore influence each other in treatment. The new departure of this publication lies in the fact that, restricting the field to the United States, it considers the American methods of treatment of the metals from the mine through the smelter to the market of the finished product. The technical processes are given with sufficient details to be clear even to the reader not especially versed in this branch of engineering.

The time of writing such a work is opportune, as some of the founders of the modern American lead-smelting practise are still actively engaged in their profession, and as the fathers of the first industrial production of zinc are still living; nor could the work have fallen into better hands than those of the author, who is well-known to the mining and metallurgical profession as an engineer, as a writer on subjects relating to lead and zinc, and as the editor of one of our leading technical journals and annuals.

The introduction gives a brief and concise review of the history of the two metals in this country. The first part, which deals with lead, is much longer than the second, devoted to zinc. This was to have been expected, as while lead was first mined in the early part of the seventeenth century, zinc was not produced until two centuries later.

The history of lead begins with an account of the occurrence of lead ores. The discussion outlines the leading geological features of the deposits, but dwells more upon the character and grade of the ores, and upon the industrial conditions which governed the mining operations. This is followed by the chronology of the history of lead-mining, which starts from the first record of 1621, when lead was mined and smelted near Falling Creek, Va., and records the leading events down to 1906. Chapter III. gives a valuable résumé of the development of the blast-furnace practise of smelting silver-bearing lead ores, and of the treatment of silver-free lead ores in the ore-hearth and the reverberatory furnace. It shows how blast-furnace smelting developed from crude beginnings into its present unsurpassed excellence by the application of science to art, and by concentration of operations into large, centrally located plants. In the account of the ore-hearth work the increase in yield by the recovery of fumes receives due consideration. While in smelting the work of Arents, Eilers, Hahn, Raht and others is recorded, in the chapter on refining we should have liked to see mentioned the invention of the Steitz siphon,

which changed the refining practise as did the Arents siphon tap the blast-furnace work, and the systematization of the complications in the Parkes process, which is more largely due to E. F. Eurich than to anybody else, and which forms the basis of the modern American practise. We miss also any record of some early eastern refineries, as, *e. g.*, the Delaware Lead Works at Philadelphia, and other smaller plants around New York. Chapters V.–XII. give a detailed history of the mining and metallurgical operations of the several states and territories. The production of metal at different periods is usually given, although in some cases, *e. g.*, in Montana, the data are missing. The remaining 55 pages of the 255 given to lead deal with the statistics of production, consumption and prices, with the commercial conditions, the tariff on lead, the labor conditions and with trade agreements and combinations.

The second part, which takes up 90 pages, treats of the history of zinc according to the same general plan as followed with lead. The mechanical concentration of zinc ores, which plays such an important part in the treatment, receives a separate chapter. The chapter on the metallurgy of zinc, the author's specialty, contains a critical review of the different types of distilling furnaces which have been and are used in this country; it is a chapter which every metallurgist will study with profit and pleasure.

The book, as a whole, is most satisfactory, as it is replete with valuable information presented in an interesting way. Last, but not least, it has a full index which enables the student to look up points upon which he desires enlightenment.

H. O. Hofman

SCIENTIFIC JOURNALS AND ARTICLES

The American Naturalist for January begins with the first part of a paper by Robert F. Griggs, on "Juvenile Kelps and the Recapitulation Theory." J. Stafford describes "The Larva and Spat of the Canadian Oyster," giving special attention to the microscopic stages mostly omitted in the work of W. K. Brooks. Waldemar Jochelson presents some interesting notes on "Traditions of the Natives of Northeastern Siberia about the Mammoth" and there are other notes on "The Age of Trotting Horse Sires" and "The Influence of Environment upon Animals."

The American Museum Journal for January has articles on "The Duck Hawk, Hackensack Meadow, and Egret Groups," "Two Noteworthy Museums" (the Congo Museum, Brussels, and Senckenburg Museum, Frankfurt), "The International Tuberculosis Exhibition" and "An Ethnological Trip to Lake Athabasca," besides notes, lists of members elected since the last issue, and the lecture announcements.

The Bulletin of the Charleston Museum for December gives an account, with plan, of "The New Building" which contains the collections, library and lecture room. A note on "The History of the Museum" shows that so late as 1843 it was still under the auspices of the Literary and Philosophical Society of Charleston.

The Museum News of the Brooklyn Institute for January contains an article on "The Hoatzin," by Geo. K. Cherrie, which gives a very full account of this interesting bird and includes a considerable amount of new information gathered by Mr. Cherrie. A note on the leather-back turtle given by the New York Aquarium, states its weight to have been a little over 840 pounds; extreme length, following curve, 6 feet, 10 inches, from flipper to flipper over shoulders, 8 feet, 9 inches. The Children's Museum section gives "Some Evidences of Progress in 1908" in the matters of increased attendance by both children and teachers, and an increasing use of the collections and library.

BOTANICAL NOTES

PHYSIOLOGY AND ECOLOGY

Alfred Dachnowski's brief paper on "The Toxic Property of Bog Water and Bog Soil" (*Bot. Gaz.*, Aug., 1908) is an attempt to contribute something to the solution of the problem of bog conditions so far as vegetation is concerned. Studies were made of a bog island in Buckeye Lake in central Ohio which ap-

peared to confirm the observer in the view that bog-water does contain toxic substances.

Geo. F. Freeman tells (*Bot. Gaz.*, Aug., 1908) of "A Method for the Quantitive Determination of Transpiration in Plants," which consists in using phosphorus-pentoxid U-tubes through which a current of air is drawn by an aspirator. This air current previously flows over the enclosed foliage of the plant under examination, and the moisture which it contains (as a consequence of transpiration) is absorbed by the phosphorus-pentoxid. The increase in weight of the latter enables the experimenter to determine the amount of transpiration.

Somewhat like the preceding is Dr. G. J. Peirce's paper on "A New Respiration Calorimeter" (*Bot. Gaz.*, Sept., 1908) in which after pointing out some errors and crudities in some popular lectures and experiments he describes the simple apparatus which he has found useful. Dewar flasks (with double walls enclosing a vacuum) were used, and it was found that these when silvered enabled the experimenter to obtain results that were quite impossible with other apparatus. Dewar flasks are also popularly known as "thermal bottles," but those supplied in chemical glassware are more serviceable and less expensive.

The question of the effect of illuminating gas upon plants is one of much popular interest and has been investigated by Messrs. Crocker and Knight and the results published in a paper ("Effect of Illuminating Gas and Ethylene upon Flowering Carnations") in the *Botanical Gazette* for October, 1908. They find that one part of gas in 40,000 parts of air kills the young flower buds, and that 1 part of ethylene in 1,000,000 parts of air is harmful.

J. F. McClendon's paper "On the Xerophytic Adaptations of Leaf Structure in Yuccas, Agaves and Nolinas" (*Am. Nat.*, May, 1908) brings together a number of interesting structural details in regard to the epidermis, stomata and general leaf-structure of these plants.

Here should be noticed Professor L. H. Harvey's very helpful paper on the "Floral Succession in the Prairie-grass Formation of Southeastern South Dakota" (*Bot. Gaz.*, Aug. and Oct., 1908) in which he gives a good idea of the vegetation of the region by an unusually clear discussion, aided by carefully selected photographs.

A suggestive paper entitled "A Study of the Variation of the Number of Ray Flowers of Certain Compositae" by Mr. W. Dudgeon recently appeared in the *Proceedings of the Iowa Academy of Sciences* (Vol. XVI.), in which the author shows by careful counts of several thousand heads from different localities, first, that there is a wide variation in the number, and second, that the highest numbers are the same in the different localities. Thus in *Rudbeckia hirta* the rays range from 2 to 28, with the greatest number of heads having 13. *Rudbeckia triloba* ranges from 5 to 14, with 8 as the normal, while in *Helianthus grosse-serratus* the range is from 7 to 25, with 13 as the normal.

Dr. Henri Hus contributes a paper in the February *American Naturalist* to the obscure subject of teratology, under the title of "Fasciations of Known Causation," in which he enumerates four "causes": (1) mechanical, (2) cases where no injury can be traced, (3) fungi, (4) insects. In his paper these are discussed at length, and numerous examples are cited.

ECONOMIC BOTANY

F. C. STEWART, of the New York Agricultural Experiment Station (Geneva), prints an instructive summary of the botanical investigations made in the station during the past twenty-five years. And it is an excellent record, and had the station accomplished no more in this time than is here enumerated in one department alone, it would have fully repaid the state for the money expended. On looking over the paper one is amazed at how much has been done in these twenty-five years. The diseases of more than thirty kinds of plants have been studied, including most of the standard crops of the state, as apple, asparagus, bean, beet, cabbage, carnation, cauliflower, celery, etc. The alphabetical arrangement makes it easy to find what has been done in the study of the diseases of this or that

plant. Incidentally it becomes a handy reference to the literature of the plant diseases investigated at this station.

H. S. Jackson's address on the "Development of Disease-Resistant Varieties of Plants," given before the Massachusetts Horticultural Society, March 14, 1908, and printed in its proceedings, is a clear popular discussion of a most important but poorly understood subject. Recognizing that "spraying is a nuisance at best" the speaker urged that more attention should be given to the development of varieties which are resistant to disease, suggesting (*a*) the selection of individuals, (*b*) the selection of varieties and (*c*) hybridization followed by selection of varieties and individuals. Brief discussions of what has been accomplished in regard to wheat, clover, cow peas, potatoes, tobacco, cotton, etc., are given which will astonish those who have not followed the work of the last few years; the difficulties are candidly pointed out, and something is said as to the cause of immunity, and the possibility of artificial immunity.

Dr. E. M. East's paper, entitled "A Study of the Factors Influencing the Improvement of the Potato" (Bull. 127, Ill. Expt. Station) is valuable not only from a practical standpoint, but also for the history of the potato which is given in the introductory pages. After this, methods of breeding, inheritance of characters in tuber selections (in which the author regards the gain as doubtful), degeneration of varieties (the author concluding that varieties do not run out), mutations, etc., are taken up in succession. The author suggests three possible methods of improvement, viz., (1) crossing of desirable plants, (2) selections of the most desirable fluctuations among the plants and tubers of a variety, (3) selection of discontinuous variations and a study of ways of causing them, and regards the first as most promising.

Here should be noticed J. E. Rockwell's "Index to Papers relating to Plant-Industry Subjects in the Year-books of the United States Department of Agriculture," which will save much time and labor to the botanist who has occasion to refer to the many valuable botanical papers published in the agricultural year-books.

Three recent papers by Dr. Kraemer in the *American Journal of Pharmacy* are of interest to the plant histologist as well as the pharmacist, viz., "Microscopical and Chemical Examinations of Black Pepper," the same for commercial ginger, and some distinguishing characters of belladonna and scopolia. Each paper is well illustrated by many clear figures.

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SPECIAL ARTICLES

SEX DETERMINATION AND PARTHENOGENESIS IN PHYLLOXERANS AND APHIDS

The phylloxera of the hickories offer exceptional opportunities for a study of sex-determination and parthenogenesis. In some species three generations can be followed within the same gall—two parthenogenetic and one sexual. We can determine the number of males and females that have descended from the same fertilized egg, as well as the influence of external conditions in affecting the number and kind of individuals in each generation. Immense numbers of eggs can be obtained. They furnish also excellent, although difficult, cytological material.

During three years I have studied the cytological aspects of the life cycle and can now present an almost complete account of the remarkable chromosomal changes that occur in connection with sex-determination.

I wish to lay especial emphasis on three points:

1. In many insects it has been found that sex is connected with, or produced by, two kinds of spermatozoa. But in phylloxerans, aphids, bees, ants, in certain saw-flies, in daphnians and in hydatina, the fertilized eggs produce only females. In the phylloxerans and aphids the result is connected with the formation of only functional female-producing spermatozoa—the male-producing sperms degenerate. One may suspect that similar conditions are to be found in the other groups, and the facts of spermatogenesis in the bee, wasp and ant, support such a view.

2. The females that result from the fertilized egg produce subsequently both males and females parthenogenetically. Clearly the egg as well as the sperm contains factors that determine sex. I have found, in fact, that the same method used by the sperm is also made use of by the egg.

3. I wish to raise certain questions connected with the mechanism by means of which males and females are produced. It has generally been assumed that chance alone determines into which sperm the sex chromosome passes. There are indications in the egg that this mechanism is not a chance result, but that behind it lie a series of preliminary events that are equally to be reckoned with as sex-determining factors.

The life cycle of a typical species of phylloxeran consists of the stem-mother (arising from the fertilized winter egg), of a second winged generation (produced by the stem-mother), and of sexual males and females—mere pigmies in size—that come from the winged individuals. The winged individuals are of two kinds, those bearing large eggs that produce the sexual females, and those bearing small eggs that produce the males. Certain species deviate from this rule. I shall refer to one such species later.

Phylloxera fallax has the following chromosomal history. The polar spindle of the egg laid by the stem-mother has twelve chromosomes. One polar body is extruded. Twelve chromosomes remain in all of the eggs and are found in the somatic cells of the winged generation.

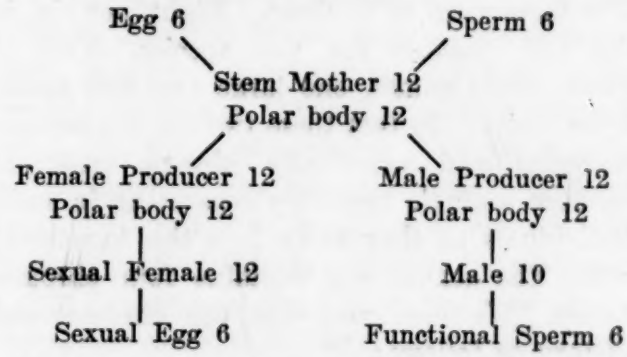
The polar spindle of the female egg laid by a winged individual contains twelve chromosomes. One polar body is extruded, and twelve chromosomes remain in the egg to give this number to the somatic cells of the sexual female.

The polar spindle of the smaller male egg also contains twelve chromosomes. One polar body is given off. Ten chromosomes remain in the egg, and this number characterizes all of the body cells of the male, as well as the spermatogonial cells. Evidently two chromosomes have disappeared when the polar body is produced.

In the first spermatocytes six chromosomes appear. At the first division four of these divide equally, but two do not divide; they are the accessories or sex chromosomes and pass to one cell. This cell becomes the functional sperm; the other, containing four chromosomes, degenerates. At the second spermatocyte division all six chromosomes in the functional spermatocyte divide equally, so that each of the two spermatozoa gets six chromosomes.[1]

The sexual egg contains a polar spindle of six chromosomes. Presumably two polar bodies are formed and six chromosomes remain in the pronucleus.

With these facts we can reconstruct the life cycle of the chromosomes.



Before commenting on these results I wish to call attention to another species, *Phylloxera caryæcaulis.*

In this species there are six chromosomes in the polar spindle of the egg laid by the stem-mother. One polar body is extruded. The somatic cells of the embryos contain six chromosomes.

The polar spindle of the female egg contains six chromosomes. Six are given off in the single polar body, and six remain in the egg.

The polar spindle of the male egg also contains six chromosomes, *but they are of different sizes from those in the female egg.*

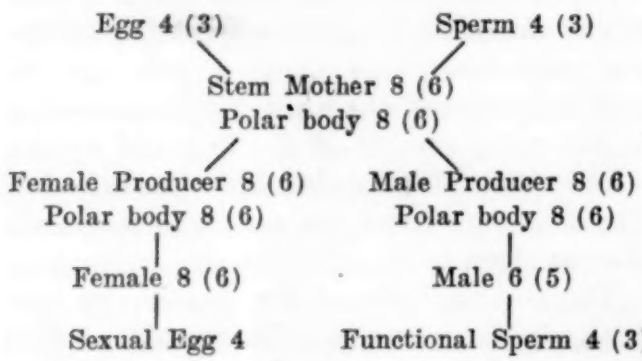
[1] In the aphids also two kinds of spermatozoa are formed. The accessory—single in this case—passes into only one of the spermatocytes. This fact I determined in the winter of 1907–8 and von Baehr and Stevens have also reached the same conclusion (1908).

Six (or more) are given off in the single polar body, but only five are found in many of the male eggs—others contain six (five large and one small). I shall clear up this difficulty later.

In the spermatocytes three chromosomes often appear—at other times four. There are found one or two accessory chromosomes. One cell gets three—or four—the other always two. The former produces the functional sperm; the latter degenerates.

In the second spermatocyte all the chromosomes divide equally in the functional cell. The rudimentary cells do not divide, and later degenerate.

The occurrence of two kinds of males with five or six chromosomes and of two kinds of spermatocytes has given endless trouble and has delayed publication for nearly a year. The facts seem to be these. Eight, not six, is the full number for this species. Two of these chromosomes, one large and one small, often unite. In fact these two are the two accessories and practically always unite to produce a single accessory separating in some individuals as they move into the functional cell. The sexual egg contains four chromosomes. We can construct the chromosomal history as follows:



The most important fact brought out by these results is that in the male egg a redistribution of the eight chromosomes occurs, so that the two small ones pair, and their mates, the two large ones, also pair. This union is evidently preparatory to the extrusion from the male egg of two entire chromosomes which reduces the number in the male by two.

We catch a glimpse here of a mechanism preceding the differential division of the chromosomes that determines the production of males.

This discovery suggests many further questions. I shall call attention to but one—the most important.

In both species we see that male eggs and female eggs are determined as such before there is any loss of chromosomes. The total number of chromosomes is present, yet one egg is large and the other small. The preliminaries of sex-determination for both sexes go on in the presence of all the chromosomes. The male itself is *produced* only *after* the elimination of two of the sex chromosomes, but the sexual female and the parthenogenetic female are both produced in the presence of all of the chromosomes. Clearly, I think, the results show that changes of profound importance may take place without change in the number of chromosomes. Equally clearly emerges the fact that the male develops after the loss of two chromosomes. This latter result shows that in the male parthenogenetic egg sex is connected with the same process found in the sperm of other species of insects.

In conclusion I wish to call attention to the sex ratios in the two species referred to.

Phylloxera fallax produces its sexual forms within the galls. The males and females crawl out of the galls, that open to allow their exit, pair, and deposit the eggs on the stems. A count showed that to 1,067 female eggs there were 1,049 male eggs in the galls—nearly an equality in number of the sexes.

Phylloxera caryæcaulis, on the other hand, produces winged forms that leave the gall and fly out in the air. Those that alight on the leaves of the hickory deposit their eggs on the under sides of the leaves. In this species a count of eggs *on the leaves* gave 1,316 male eggs and 296 female eggs, *i. e.,* nearly 4.4 to 1. More important are the counts of male and female *producers* within each gall. A large number of such counts have been made, of which the following give a fair idea: These results show a large preponderance of male producers; they also show that in some cases only male producers appear and in one

Male Producers	Female Producers	Male Producers	Female Producers
120	1	229	0
23	8	390	14
331	105	185	0
32	1	127	0
106	2	219	29
152	177	209	9
291	0	0	328
240	0	3	386
323	3		

case only female producers. When it is recalled that all the descendants can be traced to a single egg fertilized by a "female-producing" sperm the results are significant. It is obvious that while the sex of the fertilized egg is connected with the "female-producing" sperm, the subsequent progeny may be either males or females or a mixture of both. Either external conditions determine the result (for which there is no evidence), or else there is a strong "prepotency" of the egg or sperm in one or the other direction.

When it is recalled that the division into male layers and female layers takes place one generation prior to the formation of the sexes, it will be manifest that the conditions that determine the proportion of males and females, *i. e.*, sex-determining factors, are to be sought in a mechanism that lies behind the one that excludes two chromosomes from the male egg.

Equally important is the fact that in the latter process of elimination the result is not haphazard, for the eliminated chromosomes always pass into the polar body of the male egg. Since we can identify this egg before the elimination, we know that we are dealing here also with an ordered series of events, and not with an accidental shifting of chromosomes into one or another cell.

T. H. MORGAN
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MOMENTUM EFFECTS IN ELECTRIC DISCHARGE

IN SCIENCE of July 17 and December 4, the writer has given some account of experiments which seem to indicate momentum effects, in electrical discharges around a right angle in a wire. One interesting feature of the work was the formation of shadow pictures of thin glass slides upon which lines had been scratched. At the Baltimore meeting of the American Association for the Advancement of Science, a series of these pictures was shown, some of which were of special interest.

A sheet of hard rubber one sixteenth of an inch in thickness was pierced with a large number of holes of various diameters. This sheet was laid upon the photographic film within a hard rubber holder. The wire angle from which the fogging effects came was just above the cover, and about 5 mm. from the film. The holder rested upon a sheet of glass, 2 or 3 cm below, which was a grounded metal plate. The film was more strongly fogged at the bases of the larger holes than at those of the smaller ones. The electrons were apparently deflected to the sides of the smaller holes to such an extent that few of them reached the film at the bottom. Holes directly below the wire gave images with sharp outline. Those to one side gave images having on the sides remote from the wire diverging lines indicating the repulsion of the accumulating electrons on the film by the wire above, and their repulsion for each other. The comparison of such shadow images with those made by light shining through the same holes showed differences of a very marked character.

Another interesting shadow picture made just before leaving home, was produced by replacing the pierced rubber plate by small fibers of glass, laid on the film at right angles to the wire above. These fibers were about half a millimeter in diameter. Some of them were hollow tubes and some were solid. The tubes gave shadows of uniform density. The solid fibers showed conclusive evidence of refraction. In every case the shadow image shows a sharp black line along its center, where the fiber made contact with the film.

Wood, of Johns Hopkins University, suggested that this might indicate the presence of high frequency ether waves, and suggested the use of red or yellow glass, with the other glass fibers.

On returning home Wood's suggestion was carried out. After many attempts two fibers of glass, the one of colorless and the other of red sealing in glass, each having the same diameter, were prepared. This diameter was 0.079 cm. The red glass gave a slightly less sharply defined focal line. There is little if any absorption. By pushing the exposure, diverging discharge lines were shown at either end of the block focal line. This gives unmistakable evidence of the action of negative electrons.

On using a red rod of diameter 0.420 cm. the shadow picture showed white along the line of contact with the film. The absorption was then complete.

Francis E. Nipher

SOCIETIES AND ACADEMIES

THE ANTHROPOLOGICAL SOCIETY OF WASHINGTON

The 422d regular meeting, on October 13, 1908, was addressed by Major Charles E. Woodruff, surgeon, U. S. A., on "Anthropological Studies on the Effects of Light."

Major Woodruff briefly reviewed the various advances which have been made in the study of the effect of light on organisms. He gave special attention to the value of light in the treatment of tuberculosis. It was thought, said Dr. Woodruff, that fresh air, good food and abundance of light, were the three most beneficial things in the treatment of this disease. He had reached the conclusion that the last factor was harmful, and that the success of certain cloudy regions was due to the lesser degree of light; and that brilliant deserts increased the mortality to an alarming extent.

The paper was discussed by Professor McGee, Dr. Hrdlička, Dr. Lamb and others.

The 423d regular meeting, on November 10, 1908, was a memorial meeting for Professor Otis Tufton Mason, of the National Museum, whose death occurred on November 5. Appropriate remarks on his life and varied activities were made by Dr. Theodore Gill, Dr. F. W. True, Dr. Aleš Hrdlička, Mr. Charles K. Wead and several others. Dr. Hrdlička read from the autobiography which Professor Mason had prepared several months before his death.

At the 424th regular meeting, on November 24, 1908, Dr. Aleš Hrdlička gave a synopsis of the results of his investigations among the various Indian tribes of the United States for the International Congress on Tuberculosis.

Doctor Hrdlička visited the Winnebago, the northern Sioux, the Quinaielt, the Hupa and the Mohave tribes. Among all these peoples, Dr. Hrdlička describes the conditions as most appalling, giving rise to the belief that in a few years these tribes will be wasted to small remnants. The housing, food and personal habits are of the most primitive character, and there seems to be an utter disregard of all rules for the prevention of the spread of tuberculosis. Perhaps the most alarming conditions were found among the virile Sioux, who are rapidly succumbing to this dread disease. He held that in most cases the ultimate cause of the ravages of consumption among the Indians is due to the adoption of clothing, houses, food, etc., of the whites, and the lack of knowledge as to the communicability of disease.

The results of Dr. Hrdlička's researches will be published in the forthcoming report of the International Congress on Tuberculosis.

At the 425th regular meeting, on December 22, 1908, Dr. J. W. Fewkes read a paper illustrated with lantern slides on the excavation and repair work at Casa Grande, done by the Smithsonian Institution during the past two winters. The prehistoric settlement, of which Casa Grande is the best preserved building, was found to include several rectangular walled enclosures (compounds) in an area of several acres. Five of these compounds were excavated and repaired. Views were shown of mounds before excavation and others illustrated bird's-eye views of the same in their present condition.

The character of the repair work, especially the means adopted to preserve the walls from the elements was described and illustrated.

At the 426th regular meeting, on January 5, 1909, the following program was presented:

"Expedition to Sian-Fu, China, to Procure a Replica of the Nestorian Tablet," by Mr. Fritz Von Holm.

This tablet is dated A.D. 781 and contains an inscription of about 2,000 Syriac characters giving the part of Asia from which this body of Christians had come, a list of the benefits conferred on them by the Chinese emperors and other matters of historical importance. It was discovered in modern times in 1625 and set upon a stone pedestal in the shape of a turtle, but although visited occasionally, little care was taken of it until 1907, when the interest excited by Mr. Von

Holm's journey induced the officials to remove it to the Peilin or "forest of tablets," where it will be protected from the weather and its life prolonged many years. Mr. Von Holm recounted the interesting details of his expedition, the various difficulties which beset his work and the final deposit of the replica in the Metropolitan Museum of Art in New York. The lecture was illustrated by about forty excellent lantern slides.

"Remarks on Nestorianism," by Dr. I. M. Casanowicz.

This address was largely in illustration of the paper preceding, and consisted in a brief review of the past history and present condition of the Nestorian sect. Unlike most Christian bodies, Nestorians were fostered by both Persians and Arabs, and at the zenith of their power under the latter the Catholicos, or supreme head of the Nestorian Church, had under him twenty-five metropolitans, each of whom in turn was over not less than five bishops. Nestorians penetrated to China, Ceylon and India, where they were found by the Portuguese and are known as Christians of St. Thomas. At the present time a portion of the Nestorians of southwestern Asia have united with Rome, while those who still maintain their independence, numbering about 70,000, have been the object of labors by Protestant missionaries from England and America.

AT the 427th regular meeting, on January 19, 1909, Mr. Juul Dieserud presented a paper on "The Scope and Content of the Science of Anthropology." Mr. Dieserud was originally led to take up this problem in cataloguing scientific works, first at the Field Columbian Museum, Chicago, and later at the Library of Congress. His attitude was, therefore, that of the librarian and not of the working anthropologist, and was governed by a study of the attempted classifications of professional anthropologists as compared with the actual works requiring classification. It followed closely, though with elaboration in many points and condensation in others, the course of his argument in his book bearing the same title.

The paper was discussed at some length by Professor McGee, Dr. Fewkes, Dr. Swanton and Dr. Folkmar.

WALTER HOUGH,
Secretary

THE GEOLOGICAL SOCIETY OF WASHINGTON

AT the 210th meeting of the society, held on Wednesday, November 25, under informal communications, Mr. Ernest A. Shuster described briefly the original boundary stones of the District of Columbia.

Regular Program

The International Geographic Congress: Mr. DAVID T. DAY.

The Correlation of Sections Lithologically Similar: Mr. WILLIS T. LEE.

A geologic section of the coal-bearing rocks of the Grand Mesa coal field of central western Colorado, hitherto referred to the Mesaverde, was shown to be strikingly similar to the section, in the Raton coal field of New Mexico, of rocks hitherto referred to the Laramie. The evidence on which the correlations have been based is not conclusive and attention was called to the desirability of reexamining it in the light of new evidence. The recently discovered facts likely to influence the revision of correlations are: (1) a line of unconformity discovered a year ago (1907) in the Grand Mesa field separating the coal-bearing rocks into an upper and a lower member; (2) a similar line of unconformity discovered during the present season (1908) in the Raton field separating the coal-bearing rocks into two formations and (3) the stratigraphical evidence and fossil plants collected from both formations apparently indicate that the unconformity in the Raton field represents a period of erosion comparable to the post-Laramie erosion in the Denver basin.

Coon Butte or Meteor Crater: GEO. P. MERRILL.

The region of Coon Butte, near Canyon Diablo, is underlain by a light gray to buff Carboniferous (Aubrey) limestone some 200 feet in thickness, this by a light gray saccharoidal sandstone of not above 500 feet in thickness, and this, again, by a red-brown sandstone of undetermined thickness. These rocks lie nearly horizontally and are little disturbed.

The crater was described as roughly circular in outline and nearly 4,000 feet in diameter. The crater rim at its highest point is 160 feet above the level of the plain and the present bottom some 350 feet below. The rim is composed wholly of sharply upturned edges of the limestone, covered with fragments of the same, as well as fragments of the underlying sandstone, in sizes varying from microscopic to those weighing thousands of tons. Exteriorly the crater rim slopes gradually away to the plain. Interiorly the broken edges of the upturned limestone form steep,

and often perpendicular, walls. Borings made from the crater bottom vertically downward to a maximum depth of some 1,100 feet pass through a comparatively thin layer of lake bed material and talus (rarely 100 feet in thickness) into a zone of rock flour composed of the shattered granules of sandstone, and thence, at depths of about 650 feet below the crater bottom, into firm red-brown sandstone. No traces whatever were found of the ordinary volcanic products, as lava or scoria, excepting such small particles as had drifted from distant sources.

While not committing himself definitely to the theory of origin through impact of a gigantic meteorite, and while pointing out the seeming objections to such an hypothesis, the speaker showed that nevertheless no other conclusion seemed possible. Not merely had the borings in all cases reached a firm rock bottom, but the detritus thrown out, or now occupying the crater bottom, was wholly of the nature of the lime-and-sand stone (and its derivation products) forming the upper 800 feet of the strata.

The paper was illustrated by lantern slides.

At the 211th meeting of the society, held on December 9, 1908, Mr. F. E. Matthes presented the following paper: "The Glacial Character of the Yosemite Valley."

The glacial character of the Yosemite Valley is essentially a graded one—most pronounced at the upper end, gradually fading downvalleyward and ultimately vanishing at the lower end. This finds its explanation in the circumstance that the valley lay close to the periphery of the glaciated zone of the Sierra Nevada. Only the strongest glacial floods pushed any distance beyond the lower end of the valley. Most of the ice floods were of moderate volume and either barely reached its lower end or did not advance more than half way down the valley. The lower portion of the Yosemite has, therefore, been invaded by ice only at considerable intervals, and then by glacier ends mostly. Its glaciation has been feeble and stream erosion has ever had the upper hand in its fashioning. The upper half of the valley, on the contrary, has suffered frequent and relatively vigorous ice erosion and has consequently acquired a much more typical glacial aspect.

The gradation of the glacial character of the Yosemite is interrupted and obscured by a variety of aberrant sculptural features. These are explained by the selective action of the ice on rock-masses of widely different degrees of fissility. The granites of the Yosemite region are noted for their extreme and abrupt structural variations; they range in character from the schistose to the massive. The ice work in the valley was consequently subject to the controlling and directive influences of these exceptionally diverse structures. Again, the relative potency of these structural controls was the more marked because of the moderate size and disrupting power of the ice masses involved.

At the close of Mr. Matthes's address the sixteenth annual meeting of the society was held for the purpose of electing officers, and the following officers were elected for the ensuing year:

President—Mr. George Otis Smith.

Vice-presidents—Mr. M. R. Campbell and Mr. T. W. Stanton.

Secretaries—Messrs. Philip S. Smith and F. E. Matthes.

Treasurer—Mr. C. A. Fisher.

Members at Large of the Council—W. C. Mendenhall, Geo. W. Stose, Geo. H. Ashley, E. S. Bastin, L. C. Graton.

Ralph Arnold,
Secretary

THE CHEMICAL SOCIETY OF WASHINGTON

The 187th regular and 25th annual meeting of the Washington Chemical Society was held at the Cosmos Club, Thursday evening, January 14, 1909. President Walker presided, and the attendance was 80.

Two papers were read, viz.:

"Technical Analysis of Water," by R. B. Dole, of the Geological Survey.

"Prevention of Dust on Highways," by Prevost Hubbard, of the Division of Public Roads.

The report of the secretary showed that 84 new names had been added to, and 42 names removed from the list of members during the past year. The membership of the society is now over 230. A proposed amendment to the by-laws, changing the time and manner of holding the election of officers, was submitted. The election of officers resulted as follows:

President—P. H. Walker.

First Vice-president—G. H. Failyer.

Second Vice-president—W. W. Skinner.

Secretary—J. A. LeClerc.

Treasurer—F. P. Dewey.

Extra Members of the Executive Committee—H. C. P. Weber, M. X. Sullivan, H. E. Patten, H. C. Gore.

J. A. LeClerc,
Secretary.